The State Board of Health

OF MASSACHUSETTS

A Brief History of Its Organization and Its Work

1912

STATE BOARD OF HEALTH

OF

MASSACHUSETTS.

A BRIEF HISTORY OF ITS ORGANIZATION AND ITS WORK, 1869-1912.

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1. THE STATE BOARD OF HEALTH OF MASSACHUSETTS, 1912.

HENRY P. WALCOTT, M.D., *Chairman*,	of Cambridge.
CLEMENT F. COOGAN,	of Pittsfield.
JOSEPH A. PLOUFF,	of Ware.
JULIAN A. MEAD, M.D.,	of Watertown.
HIRAM F. MILLS, C.E.,	of Lawrence.
ROBERT W. LOVETT, M.D.,	of Boston.
C. E. McGILLICUDDY,	of Worcester.

Secretary.
MARK W. RICHARDSON, M.D.

Assistant to the Secretary.
WILLIAM C. HANSON, M.D.

Engineer.
X. H. GOODNOUGH, C.E.

Pathologist.
THEOBALD SMITH, M.D.

Analyst of Food and Drugs.
HERMANN C. LYTHGOE, S.B.

Chemist.
H. W. CLARK.

2. A BRIEF HISTORY OF THE ORGANIZATION OF THE STATE BOARD OF HEALTH.

Public health questions in Massachusetts were first studied in a comprehensive manner by a commission appointed in 1849 to report to the Legislature a plan for a sanitary survey of the State.

The commission consisting of Lemuel Shattuck of Boston, Nathaniel P. Banks, Jr., of Waltham and Jehiel Abbot of Westfield, made an extensive investigation of all causes affecting favorably or unfavorably the health of the inhabitants of the Commonwealth, and the following year submitted a report to the Legislature. This report is the best public document ever written in Massachusetts, and one of the great documents of the world. It includes specific recommendations for legislation leading to a more efficient control of the factors influencing the health of communities and individuals. In its introduction the report contains the following statement: —

> We believe that the conditions of perfect health, either public or personal, are seldom or never attained, though attainable; — that the average length of human life may be very much extended, and its physical power greatly augmented; — that in every year, within this Commonwealth, thousands of lives are lost which might have been saved; — that tens of thousands of cases of sickness occur which might have been prevented; — that a vast amount of unnecessarily impaired health and physical debility exists among those not actually confined by sickness; — that these preventable evils require an enormous expenditure and loss of money, and impose upon the people unnumbered and immeasurable calamities, pecuniary, social, physical, mental and moral, which might be avoided; — that means exist within our reach for their mitigation or removal; — and that measures for prevention will effect infinitely more than remedies for the cure of disease.

The recommendations included in this report were of far-reaching importance. The commissioners recommended that a central board of health be established, which should be charged with the general execution of the laws of the State relating to the health of the inhabitants. They furthermore recommended the establishment of local boards of health; that a census be taken of the people; that there be a systematic registration of births, marriages and deaths; that all causes of diseases

be thoroughly investigated; that a sanitary control be maintained over public buildings and factories; that proper quarantine regulations be formulated; that the smoke nuisance be abated; that measures be adopted to prevent the adulteration of food and drugs; and many other matters of importance.

The recommendation of the commission of 1850 to establish a general board of health reads in part as follows: —

> The cause of Public Health needs a . . . central agency, to give to the whole sanitary movement a uniform, wise, efficient, economical and useful direction. . . . Such an agency would have an exact knowledge of the condition of every city and town in the State, and by these means of information would be able to suggest the measures best adapted to the different circumstances. They would prevent a wasteful expenditure of money in imperfect or inefficient measures. The advantages which would result to the whole State, and to every part of it, — to each and all of the inhabitants, — from the establishment of such a central General Board of Health, composed of the best scientific counsel and the best practical experience which the State can afford, having constant access to the most enlightened intellects, and to a knowledge of the labors of the best practical men in the world, and assisted by at least one mind wholly devoted to the object in view, are too great to be fully seen at once, and can scarcely be overstated or overestimated. . . . The duties of this board should be . . . to have general direction of each census; to superintend the execution of the sanitary laws of the State; to examine and decide upon sanitary questions submitted to them by public authorities; and to advise the State as to sanitary arrangements of public buildings and public institutions; to give instructions to local boards of health as to their powers and duties; to suggest local sanitary rules and regulations; to recommend such measures as they may deem expedient for the prevention of disease and the promotion of public health; and to report their proceedings annually to the State.

Lemuel Shattuck and the other commissioners of 1850 proved to be nearly twenty years in advance of their time, for the organization of a general board of health was not provided for by the Massachusetts Legislature until 1869.

In 1866 a committee of the House of Representatives had reported to the Legislature that it was not expedient to establish a State board of health, and although private individuals, including Lemuel Shattuck, had urged the necessity of such a board nothing definite was accomplished at that time.

In 1869, however, a law was enacted creating a State Board of Health to consist of seven members appointed by the Governor. This board was given general oversight of all matters relating to the health of the

people. The duties of this Board, as defined by the Legislature, were as follows: —

The Board shall take cognizance of the interests of the life and health of the citizens in this Commonwealth. They shall make sanitary investigations and inquiries in respect to the causes of disease, and especially of epidemics and the sources of mortality, and the effects of localities, employments, conditions and circumstances upon the public health; and they shall gather such information in respect to those matters as it may deem proper for diffusion among the people. It shall advise the government in regard to the location and other sanitary conditions of any public institutions, and shall report to the Legislature each year with such suggestions as to legislative acts as they may deem necessary.

Henry Ingersoll Bowditch, a prominent physician of Boston, was appointed chairman of the first State Board of Health, which position he held for over ten years, until the State Board of Health was merged with other boards into the State Board of Health, Lunacy and Charity in 1879.

Shortly after the first meeting of the Board a circular was prepared and sent out to the mayors, selectmen, boards of health of cities and towns, to all the members of the Legislature, and to all clergymen and physicians throughout the State, calling attention to the organization of the State Board of Health, describing in general its powers and duties and inviting their co-operation in the interest of public health.

The importance which Dr. Bowditch attached to the field of activity of the newly created Board can be seen from what he says in his address at the first meeting of the Board: —

As the subject matters for our discussion may be somewhat indefinite in all of our minds, I take the liberty of addressing a few words to you, in order that you may know not only what I consider the general nature of our duties, but may also understand how high I place these duties when I consider them in their relations to the present and future health of the citizens of the State. I may be mistaken in my estimate of the importance of the movement, the commencement of which to-day devolves upon us. I confess to you that I know of no higher office in the State than that which we now hold, viz., that of inaugurating the idea of "State medicine" in Massachusetts. Upon our high or low appreciation of the position and of the duties resulting from that position, and upon our wise or foolish performance of these duties, depends the success of the object aimed at in the establishment of a State board of health. The last Legislature, unconsciously, perhaps, on the part of many members thereof, has proposed a system that may be made by us capable of good to the citizens in all future time, or it may prove a perfect

abortion. Our work is for the far future as well as for the present, and at this very opening of our labors we should try to place ourselves above the region of merely local or temporary excitement or of partisan warfare, in order that we may act wisely and for the ultimate good of the whole people.

The activities of the State Board of Health during the first ten years of its existence were divergent and full of achievements. Investigations of a great number of sanitary subjects were made and many plans for sanitary reforms were carried out. The extent of these investigations can be learned by referring to the titles of the papers presented in the reports of the Board, which are published elsewhere in this volume. The reports of the Board were received with great favor not only in the various States of the union but in European countries.

In 1878 the three departments of health, lunacy and charity were merged into one Board. Dr. Bowditch and his associates were very much dissatisfied with the change.

On the organization of this new Board the duty of acting as executive health officer was imposed upon the secretary, Dr. Charles S. Folsom.

In 1880 Dr. Henry P. Walcott was unanimously elected as health officer, in which position he served until 1882, when he resigned as health officer and was appointed as a member of the Board and as chairman of the committee on health.

In 1886, by an act of the Legislature, the State Board of Health once more entered upon an independent existence, and with Dr. Henry P. Walcott as chairman and Dr. Samuel Abbott as secretary it entered upon its work with a much broader field before it than that of its predecessors. The powers conferred upon it were more decidedly of an executive character, and the duties more exacting.

Among the matters of which this Board was to take cognizance were —

1. The causes and prevention of infectious diseases.

2. The suppression of nuisances, including the regulation of noxious and offensive trades.

3. The collection and diffusion of information relative to industrial hygiene, or the effects of different occupations, industries and domestic pursuits upon people at various ages and under various conditions of life.

4. The hygiene of schools, school buildings and public institutions.

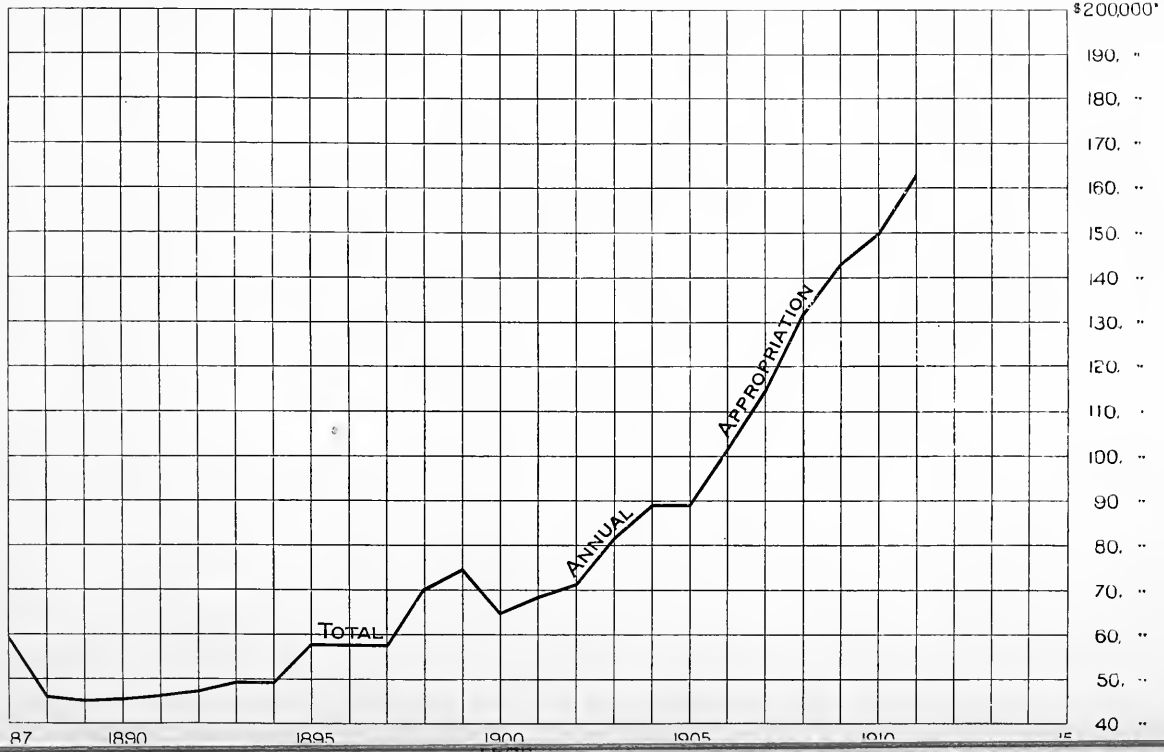
5. The examination and investigation of public water supplies and public ice supplies, and the prevention of their pollution.

6. The investigation of drainage and sewerage systems or plans, so far as they relate to the public health.

7. The disposal and transportation of the dead.

MASSACHUSETTS STATE BOARD OF HEALTH

TOTAL ANNUAL APPROPRIATIONS



8. The inspection of food, drugs and other articles affecting the public health.

9. Inquiries into the causes and means of prevention of insanity.

10. Inquiries into the amount of intemperance from the use of stimulants and narcotics, and the remedies therefor.

11. The protection of human life.

12. Investigations as to the infectious diseases of animals, so far as they affect the public health, *e.g.,* hydrophobia, trichinosis, glanders, anthrax, etc.

By another act of the same Legislature entitled "An Act to protect the Purity of Inland Waters," the State Board of Health was given the general care and oversight of all inland waters.

The history of the development of the work and achievements of the State Board of Health since its reorganization in 1886 to the present day can be seen from the reports of the various departments of the Board which are presented here.

3. DEPARTMENT OF WATER SUPPLY AND SEWERAGE.

A. ENGINEERING DEPARTMENT.

While the Department of Water Supply and Sewerage was established by an act of the Legislature in 1886, considerable work along the lines afterwards followed had been previously done. For instance, in 1872 the Legislature resolved that "the Board of Health be requested to consider the general subject of the disposition of the sewage of towns and cities, having in view, first, its utilization as a fertilizer; second, sanitary effects of draining the same into the waters of the Commonwealth: third, the increasing joint use of the water courses for sewers and as sources of supply for domestic use by the people of the Commonwealth."

The Board in the following year made a comprehensive report upon sewage and sewerage, the pollution of streams and the water supply of towns. This was published in the fourth annual report of the Board.

The fifth annual report of the Board contained a special report upon the present condition of certain rivers of Massachusetts, together with considerations touching the water supply of towns.

The seventh annual report contained another special report on the pollution of rivers, the water supply, drainage and sewerage of the State from a sanitary point of view and the disposal of sewage.

The eighth annual report contained a special report upon the pollution of streams, disposal of sewage, etc.

The ninth annual report, that of 1878, also had a special report on drainage and health, sewerage and pollution of streams.

The Legislature of 1881 requested the State Board of Health to report upon the pollution of the Blackstone River by Worcester. In the year 1881 the Legislature authorized a commission to consider the drainage of the Mystic and Charles River valleys.

The Massachusetts Drainage Commission, so-called, was appointed, in accordance with a resolve of the Legislature, May, 1884. The resolve under which they acted directed them to consider and report upon a general system of drainage for the relief of the valleys of the Mystic, Blackstone and Charles rivers and for the protection of the public water supplies of the cities and towns situated within the basins of said rivers; also to consider the various methods of disposal of sewage and the application of such methods to any portion of the territory mentioned under the resolve. Their report was published under date of 1886, and in concluding the same the commission stated that —

Precisely the same principle which enjoins a watchful care over the exterior waters of the State would seem to call for at least an equal solicitude concerning the abuse of its interior waters. But mindful of the tenderness with which Massachusetts has always treated her industrial classes, we think it would be wise to embrace in the enactment one peculiarly characteristic feature borrowed from the act establishing a railroad commission, and which has proved strong enough to enforce amply all the rights of the public in that class of highways called railroads. This distinctive trait is the use of advisory as distinguished from mandatory power. We think it would be well, then, for the Legislature to designate some one or more persons to look after the public interests in this direction. Let these guardians of inland waters be charged to acquaint themselves with the actual condition of all waters within the State as respects their pollution or purity, and to inform themselves particularly as to the relation which that condition bears to the health and well-being of any part of the people of the Commonwealth. Let them do away, as far as possible, with all remediable pollution, and use every means in their power to prevent further vitiation. Let them make it their business to advise and assist cities or towns desiring a supply of water or a system of sewerage. They shall put themselves at the disposal of manufactories and others using rivers, streams or ponds, or in any way misusing them, to suggest the best means of minimizing the amount of dirt in their effluent, and to experiment upon methods of reducing or avoiding pollution. They shall warn the persistent violator of all reasonable regulation in the management of water of the consequences of his acts. In a word, it shall be their especial function to guard the public interest and the public health in its relation with water, whether pure or defiled, with the ultimate hope, which must never be abandoned, that sooner or later ways may be found to redeem and preserve all the waters of the State. We propose to clothe the Board with no other power than the power to examine, advise and report, except in cases of violation of the statutes. — If such a Board be able to commend itself by its conduct to the approval of the great court of public opinion, it will have no difficulty, we think, in materially reducing the disorders and abuses which are threatening to give great trouble in future if not speedily checked. If, however, we err in this expectation, and more drastic measures prove indispensable, the mandate of the State can always be invoked to re-enforce its advice.

Finally, the report of this commission recommended a general act for the protection of the purity of inland waters. This act in substance was passed by the Legislature of 1886, and is given below. By its provisions the supervision of the water supply and sewerage of Massachusetts municipalities, including such work as should be found necessary for the carrying out of such provisions, was intrusted to the State Board of Health.

Acts of 1886, Chapter 274.

An Act to protect the purity of inland waters.

Be it enacted, etc., as follows: —

Section 1. The state board of health shall have the general oversight and care of all inland waters and shall be furnished with maps, plans and documents suitable for this purpose, and records of all its doings in relation thereto shall be kept. It may employ such engineers and clerks and other assistants as it may deem necessary; *provided,* that no contracts or other acts which involve the payment of money from the treasury of the commonwealth shall be made or done without an appropriation expressly made therefor by the general court. It shall annually on or before the tenth day of January report to the general court its doings in the preceding year, and at the same time submit estimates of the sums required to meet the expenses of said board in relation to the care and oversight of inland waters for the ensuing year; and it shall also recommend legislation and suitable plans for such systems of main sewers as it may deem necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams and inland waters of the commonwealth.

Section 2. Said board shall, from time to time as it may deem expedient, cause examinations of the said waters to be made for the purpose of ascertaining whether the same are adapted for use as sources of domestic water supplies or are in a condition likely to impair the interests of the public or persons lawfully using the same, or imperil the public health. It shall recommend measures for prevention of the pollution of such waters and for removal of substances and causes of every kind which may be liable to cause pollution thereof, in order to protect and develop the rights and property of the commonwealth therein and to protect the public health. It shall have authority to conduct experiments to determine the best practicable methods of purification of drainage or disposal of refuse arising from manufacturing and other industrial establishments. For the purposes aforesaid it may employ such expert assistance as may be necessary.

Section 3. It shall from time to time consult with and advise the authorities of cities and towns, or with corporations, firms or individuals either already having or intending to introduce systems of water supply or sewerage, as to the most appropriate source of supply, the best practicable method of assuring the purity thereof or of disposing of their sewage, having regard to the present and prospective needs and interests of other cities, towns, corporations, firms or individuals which may be affected thereby. It shall also from time to time consult with and advise persons or corporations engaged or intending to engage in any manufacturing or other business, drainage or refuse from which may tend to cause the pollution of any inland water, as to the best practicable method of preventing such pollution by the interception, disposal or purification of such drainage or refuse: *provided,* that no person

shall be compelled to bear the expense of such consultation or advice, or of experiments made for the purpose of this act. All such authorities, corporations, firms and individuals are hereby required to give notice to said board of their intentions in the premises. and to submit for its advice outlines of their proposed plans or schemes in relation to water supply and disposal of drainage or refuse. Said board shall bring to the notice of the attorney-general all instances which may come to its knowledge of omission to comply with existing laws respecting the pollution of water supplies and inland waters and shall annually report to the legislature any specific cases not covered by the provisions of existing laws, which in its opinion call for further legislation.

In 1886 the Board organized a water supply and sewerage department for carrying out the provisions of the act given above. The principal duties of the Board under the act were as follows: —

1. To have the general care and oversight of inland waters.
2. To have the custody of maps, plans, etc., made for this purpose.
3. To recommend legislation and suitable plans for systems of main sewers.
4. To cause examinations of the waters of ponds and streams to be made.
5. To recommend measures to prevent the pollution of waters.
6. To conduct experiments upon the purification of sewage.
7. To conduct experiments upon the disposal of manufacturing refuse.
8. To consult with and advise the authorities of cities and towns or with others with reference to water supply and drainage.
9. To consult with and advise manufactories with reference to the disposal of manufacturing refuse.

The act also provided that authorities of cities and towns, and all others intending to introduce systems of water supply or sewerage, should submit to the Board outlines of their proposed plans or schemes in relation to these subjects, and manufacturers intending to engage in any business, the drainage or refuse from which might tend to cause the pollution of any inland water, should also give notice to the Board of their intentions. .

After the Act of 1886 had been in force two years it was amended by the enactment of chapter 375 of the acts of 1888 which required. in addition to the provisions of the Act of 1886, that all petitions to the Legislature for authority to introduce systems of water supply, drainage or sewerage should be accompanied by a copy of the advice and recommendation of the State Board of Health thereon.

With the establishment of the water supply and sewerage department applications from cities and towns in regard to water supply and sewer-

age began to be received. There were few at first, but they have increased in number yearly, and up to the present time the total number is 2,372, the number each year being shown in the following table: —

Year.	Number of Applications.	Year.	Number of Applications.
1886,	8	1899,	79
1887,	22	1900,	104
1888,	28	1901,	105
1889,	38	1902,	93
1890,	23	1903,	129
1891,	53	1904,	125
1892,	56	1905,	105
1893,	51	1906,	130
1894,	53	1907,	125
1895,	52	1908,	134
1896,	65	1909,	128
1897,	59	1910,	139
1898,	75	1911,	176

When this work was begun the engineering force consisted of a chief engineer and one assistant. In 1912 this force is as follows: —

Chief engineer,	1
Assistant engineers,	17
Stenographers and clerks,	5

In addition to the work done by the Board under the provisions of the acts above mentioned, the consideration of numerous other special problems relating to water supply, sewerage and kindred subjects has been committed to the Board from time to time for its advice and recommendation.

Metropolitan Sewerage System.

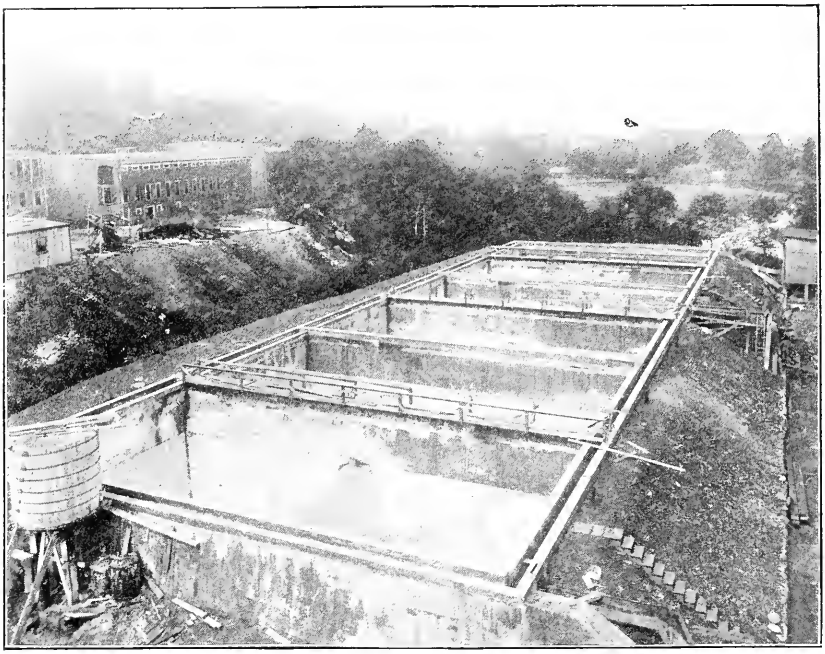
In 1887 the Board was directed to investigate and report a plan for a metropolitan system of sewerage, chiefly in the Mystic and Charles River valleys under the following legislative resolves: —

Resolves of 1887, Chapter 95.

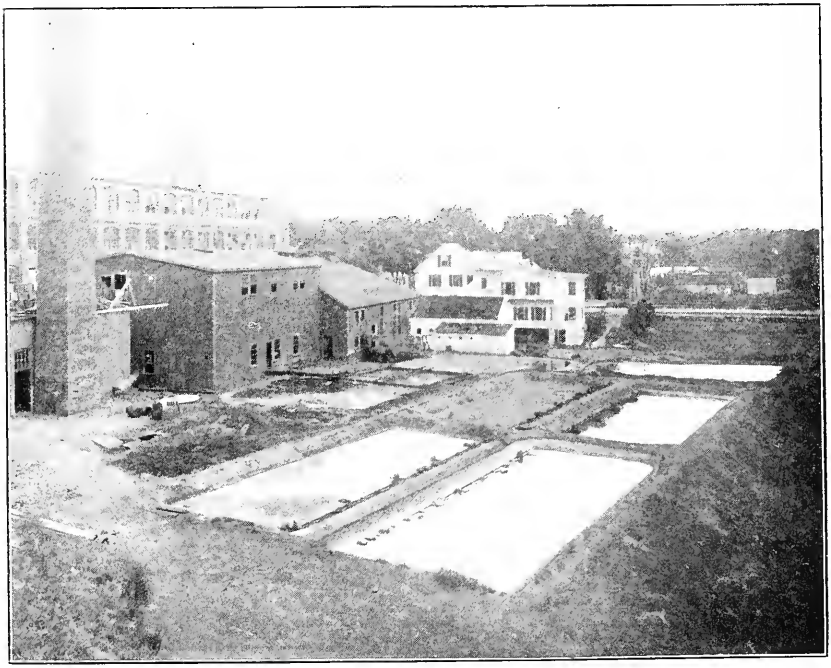
Resolve relating to sewage disposal in the Mystic and Charles River valleys.

Resolved, That the state board of health is hereby authorized and directed to consider and report a general system of drainage and sewerage for the relief of the valley of Mystic river, and so much of the valley of Charles

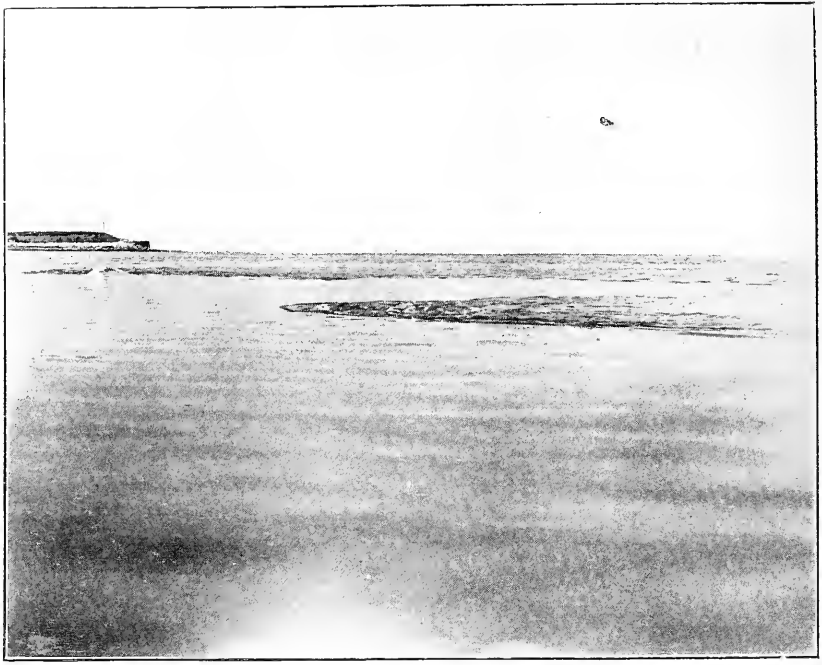
Intermittent Sand Filters for Sewage Disposal.



Works for the Treatment of Paper Mill Wastes in the Prevention of River Pollution.



Works for the Treatment of Woolen Mill Wastes in the Prevention of River Pollution.



Discharge of Sewage into Boston Harbor from North Metropolitan District.

Discharge of Sewage into Boston Harbor from South Metropolitan District.

river, if any, whose relief in the opinion of said board is to be sought in conjunction with the Mystic valley system, and for such cities and towns, or parts of cities and towns as may, in the opinion of said board, be best relieved by the use of said system; and so much of the report of the commissioners appointed under resolve approved May twenty-eighth, in the year eighteen hundred and eighty-four, as relates to the cities and towns, or parts of cities and towns, which said board shall incorporate in the system to be reported under this resolve, is hereby referred to said board for its further consideration, and it shall be the duty of said board, —

First. To designate the cities and towns, and parts of cities and towns, which shall be tributary to and embraced in the district and system so to be reported, and to define the same by their report, with plans and maps.

Second. To define and show, by suitable plans and maps, such trunk line and main branches as it shall recommend to be constructed with outlet.

Third. To define the methods by which said cities and towns, or parts of any city or town, may utilize said trunk line and main branches as an outlet of a system of sewerage and drainage for said respective cities and towns, and said parts of cities and towns, and to show the same by plans and maps.

Fourth. To cause such surveys and levels to be made as will enable said board to determine with accuracy the location and grades of said trunk line and main branches, and also such surveys and levels in said cities and towns and parts of cities and towns as will enable said board to determine with accuracy the methods by which said cities and towns and parts of cities and towns may respectively utilize said trunk line and main branches and to report such methods by plans showing the main lines by which each may so provide for itself a system of sewerage and drainage with its outlet into said trunk line or main branches.

Fifth. To define the size and capacity of said trunk line and main branches and the materials of which they should be constructed and manner of construction, and such other particulars as will enable said board to determine the probable expense thereof.

Sixth. The expenses of surveys, maps and plans made to show the method by which any city or town, or part of city or town, may utilize said trunk line and main branches shall be separately kept, and the same, showing the amount expended in each, together with the expenses of the location and grade, maps and plans of said trunk line and main branches, together with all other expenses in the premises, and the items thereof, shall be reported to the governor and council, and all such costs and expenses shall be paid out of the treasury of the Commonwealth, on bills to be approved by the governor and council.

Seventh. Each city or town which wholly or in part said board shall consider should form a part of the territory to be embraced in the system to be reported shall be notified thereof by said board as soon as said board shall determine the cities and towns and parts of cities and towns which shall constitute said sewerage and drainage district. Said notice shall contain the

names of the cities and towns wholly, and shall designate the portions of the cities and towns not wholly but in part, incorporated therein, and each of such cities and towns may confer with said board in respect to such drainage and sewerage system, and on request in writing be heard by said board on matters relating to the method of its utilizing said trunk line and main branches and the surveys, levels, maps and plans to determine and show the same, and under the superintendence of said board may, at its own expense, make its said surveys, levels, maps and plans for the use of said board; but all questions upon which any city or town shall desire to be heard shall be submitted to said board in writing with such request.

Eighth. Said board shall also consider whether any city or town within such district can more advantageously provide for itself a system of sewerage and drainage by itself and not as a part of said general system, and shall hear such city or town thereon if it shall so request, and shall also make report thereof.

Ninth. To ascertain and report the cost of the construction of said trunk line and main branches and outlet, and of the annual expense of operating the same, and also what cities and towns, or parts of cities and towns, would be obliged to pump their sewage or any part thereof, at what places, the cost of the works therefor and the annual expenses thereof: *provided, however,* the whole amount expended under the provisions of this resolve shall not exceed the sum of ten thousand dollars; and reports under the same shall be made by the state board of health to the general court on or before the first Wednesday of January, in the year eighteen hundred and eighty-nine. [*Approved June 16, 1887.*

Resolves of 1888, Chapter 63.

Resolve providing for further investigations, relative to sewage disposal in the Mystic and Charles River valleys.

Resolved, That the state board of health be requested to designate some method for the disposal of the sewage of such cities and towns as are embraced within the lower valley of the Charles river, in the report of the commissioners appointed under chapter sixty-three of the resolves of the year eighteen hundred and eighty-four, as they may not include in their report under chapter ninety-five of the resolves of the year eighteen hundred and eighty-seven, and so much of said report as relates thereto is hereby referred to said board for its further consideration. Such designation shall be made as a part of the report required by chapter ninety-five of the resolves of the year eighteen hundred and eighty-seven, and the expense thereof charged to the appropriation provided for in chapter forty-two of the resolves of the year eighteen hundred and eighty-eight. [*Approved April 24, 1888.*

The territory whose relief was provided for under these resolves included an area of 130 square miles and contained 20 municipalities

having a population aggregating about one-sixth of the total population of the State at that time. The Board considered the problem from various points of view, as follows: —

1. The method of discharging crude sewage into a strong tidal current that will convey it to sea, whence it cannot return.

2. The method of partial purification by filtration upon the bed recommended by the Massachusetts Drainage Commission by report of Dec. 24, 1885, or upon some other bed or beds.

3. By chemical precipitation and discharge of the clarified effluent into outgoing tide at one or more points.

The Board, as a result of its studies, recommended systems of sewerage for the Mystic and Charles River valleys and the various towns therein, as required by the acts, and recommended further that the sewage be discharged into the sea through an outlet located near Deer Island Light off the northerly entrance to Boston Harbor. The plan was adopted by the Legislature, and a special commission, known as the Metropolitan Sewerage Commission, was appointed to construct the works in accordance with the plans designed by the Board. The works were completed at a total cost of approximately $5,500,000, and have been in use continuously since 1894.

Improvement of Charles River.

In 1893 the State Board of Health, acting jointly with the Metropolitan Park Commission, was required by the Legislature in the following act to investigate the sanitary condition of the lower part of the course of the Charles River where it flows through the city of Boston and adjacent portions of the metropolitan district and report a plan for its improvement: —

Acts of 1893, Chapter 475.

An Act to provide for the improvement of charles river.

Section 1. The board of metropolitan park commissioners, established under the provisions of chapter four hundred and seven of the acts of the year eighteen hundred and ninety-three, and the state board of health, sitting as a joint board, shall investigate the sanitary condition and prepare plans for the improvement of the beds, shores and waters of the Charles river, between Charles river bridge and the Waltham line on Charles river, and for the removal of any nuisances therefrom, and report with their recommendations to the next general court on or before the first Wednesday in February.

Section 2. Said commissioners may employ engineers and experts and incur such expenses as may be necessary to carry out the provisions of this act, and may expend for such purpose a sum not exceeding five thousand

dollars. All bills shall be approved and filed with the auditor and allowed in the same manner as other claims against the commonwealth.

SECTION 3. This act shall take effect upon its passage.

The Joint Board subsequently recommended the construction of a dam near Craigie bridge between Boston and Cambridge, a short distance above the mouth of the river, and the creation of a fresh water basin over 8 miles in length in the heart of the metropolitan district. After further investigation by other commissions the plans were carried out as recommended in the report of the Joint Board at a cost of approximately $3,993,000.

By the provision of an act passed in 1894 the Joint Board was required to consider the improvement of an additional section of the Charles River lying above the portion provided for in the original legislation. After investigations, plans for the improvement of that section of the river were reported by the Joint Board to the Legislature in May, 1896. The recommendations of this report relating to the ownership and control of the region included in the report have been carried out, and large areas along this river, with its great advantages for outdoor recreation, have been secured and set apart for the use of the public.

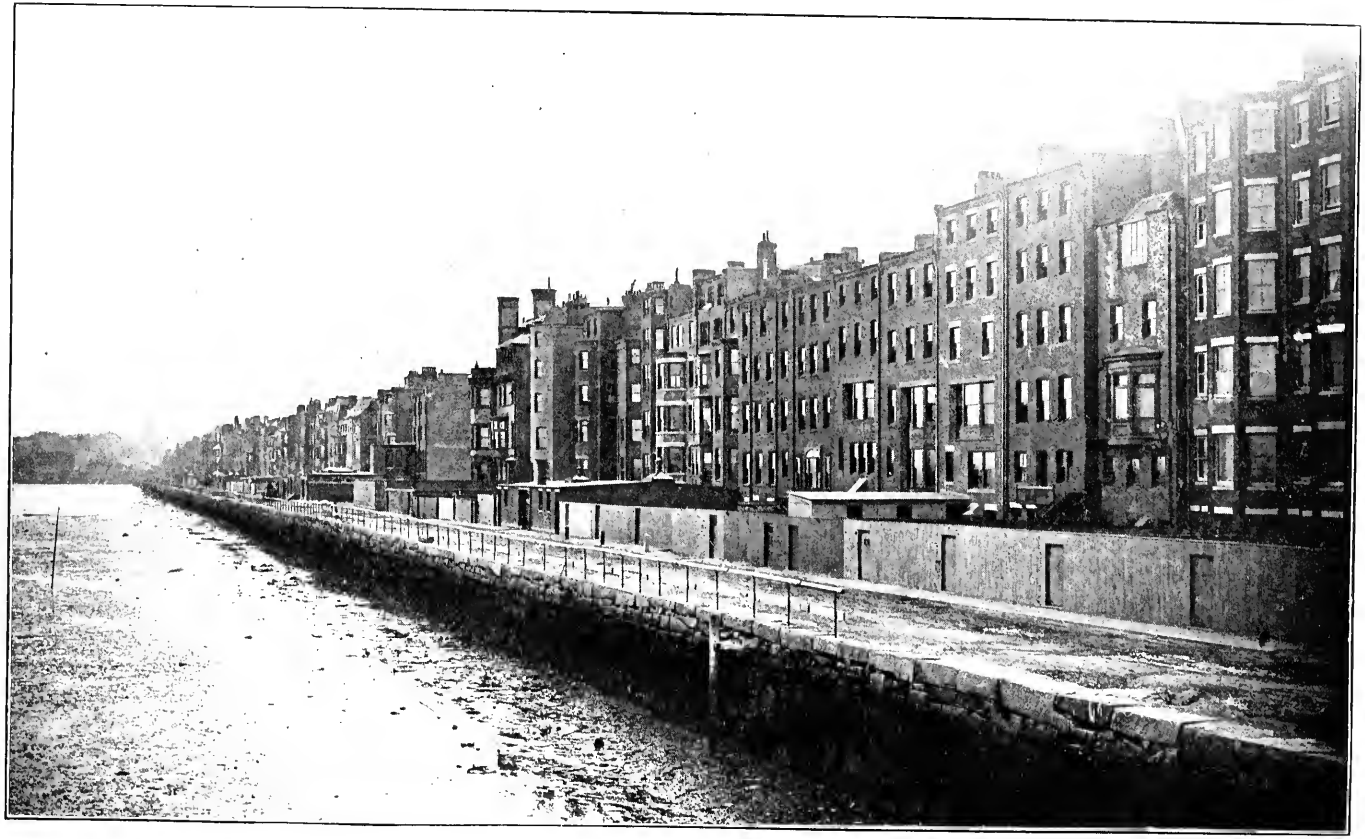
IMPROVEMENT OF THE CONCORD AND SUDBURY RIVERS.

The Concord River and its main tributary, the Sudbury, drain an extensive area of level country in the east central part of Massachusetts, and the rivers are bordered for many miles of their courses by extensive meadows which were usually wet and often inundated, even in the summer season. Previous investigations had shown that the conditions would be materially improved by removing certain bars in these rivers which obstructed the flow, and in 1894 the State Board of Health was directed to expend $20,000 in the improvement of these rivers by dredging and removing the bars which impeded the flow of the streams. The amount appropriated was subsequently increased to provide for additional work, including the reconstruction of a bridge, and the total expenditure was $23,000. The work was completed in 1897, and the expected improvement in the condition of the adjacent meadows has been fully realized.

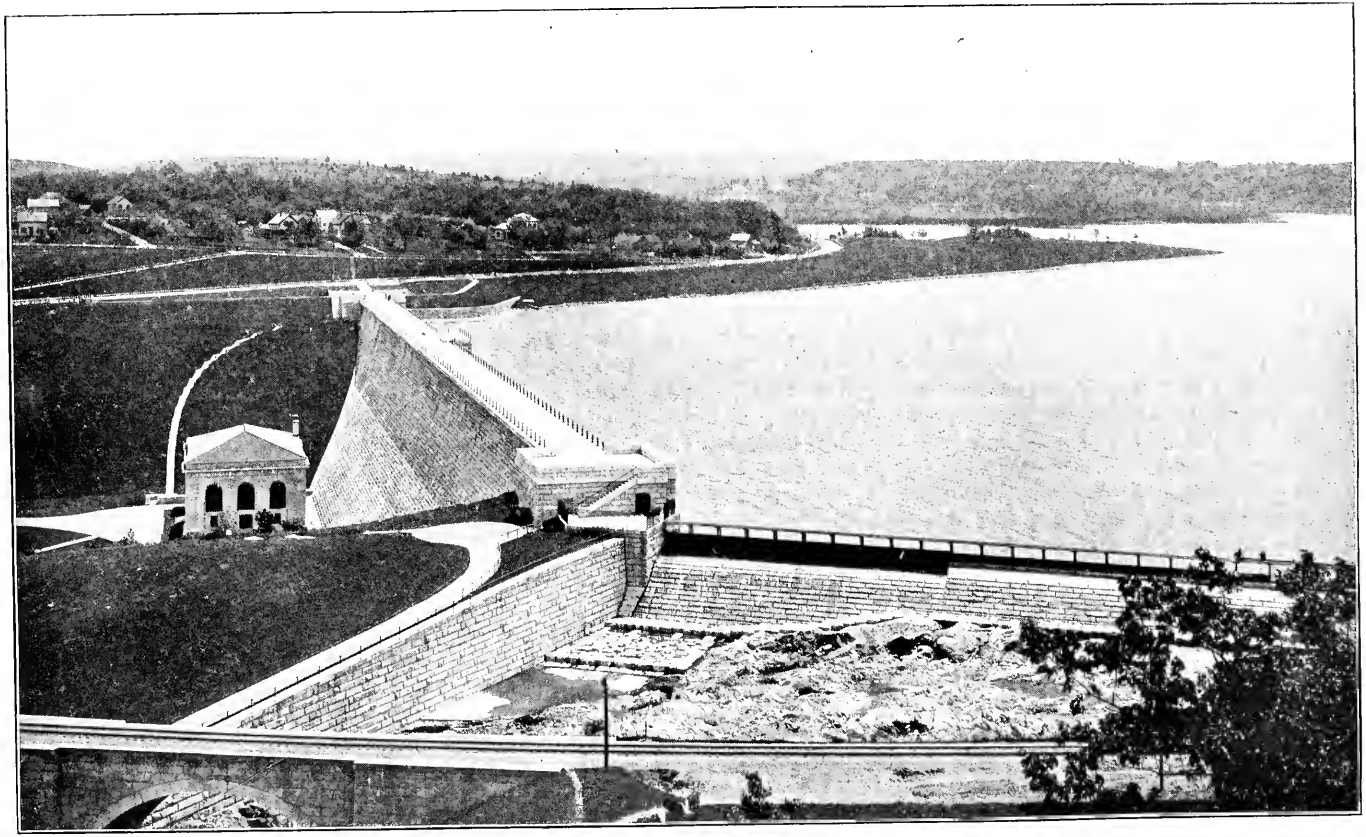
METROPOLITAN WATER SUPPLY.

By the provisions of chapter 459 of the Acts of the year 1893 entitled "An Act relative to procuring a Water Supply for the City of Boston and its Suburbs," the Board was directed to prepare a plan for providing

Improved Charles River Basin.



Charles River Basin previous to Improvement.



Metropolitan Water Works. — Wachusett Dam and Power House.

Metropolitan Water Works. — Wachusett Basin.

a water supply for the population within a radius of 10 miles from the State House in the city of Boston. The act is as follows: —

Section 1. The state board of health is hereby authorized and directed to investigate, consider and report upon the question of a water supply for the city of Boston and its suburbs within a radius of ten miles from the state house, and for such other cities and towns as in its opinion should be included in connection therewith.

Section 2. The said board shall forthwith proceed to investigate and consider this subject, including all questions relating to the quantity of water to be obtained from available sources, its quality, the best methods of protecting the purity of the water, the construction, operation and maintenance of works for storing, conveying or purifying the water, the cost of the same, the damages to property, and all other matters pertaining to the subject.

Section 3. The said board shall have power to employ such engineering and other assistance and to incur such expenses as may be necessary for carrying out the provisions of this act.

Section 4. The said board shall report fully with plans and estimates to the legislature on or before the first Wednesday in January in the year eighteen hundred and ninety-five, and shall append to its report drafts of bills intended to accomplish the recommendations of the board.

Section 5. The total amount of money which shall be expended out of the treasury of the commonwealth in carrying out the provisions of this act shall not exceed forty thousand dollars. The commonwealth shall be reimbursed for the amount expended by the cities and towns which are to receive the benefit of the system recommended in the report, in proportion to the population of each.

Section 6. Before incurring any expense the board shall from time to time estimate the amounts required and shall submit the same to the governor and council for their approval, and no expense shall be incurred beyond the amount so estimated and approved.

Section 7. This act shall take effect upon its passage.

The Board under this act presented to the Legislature in 1895 a report recommending the construction of a great reservoir on the south branch of the Nashua River, a stream draining the region about Mt. Wachusett in the hilly country in the north central part of the State. The plans included the continued use of certain portions of the former water supply system of the city of Boston and other communities, and the connection of the new system with the various parts of the metropolitan district by suitable reservoirs, aqueducts, pipe lines and other works. The plans of the Board were accepted by the Legislature of 1895, and the construction of the works in accordance with these plans was committed to a special commission, — the Metropolitan Water

Board. The construction of the works was at once begun, and the great reservoir known as the Wachusett Reservoir, having a capacity of 65,000,000,000 gallons, was filled to overflowing for the first time in the spring of 1908.

The total cost of the works, including amounts paid for existing works in other cities and towns, utilized in connection with the metropolitan system, has been (up to 1912) $41,933,000.

Salem and Peabody Sewerage.

In the year 1895 the Board was required to consider and report plans for the collection and disposal of the sewage of the city of Salem and the town of Peabody, under the provisions of chapter 112 of the Resolves of the year 1895.

Plans for a general system of sewerage and sewage disposal for the city of Salem and town of Peabody were reported, as required by the resolve, to the Legislature of 1897. These plans provided for collecting the sewage and also the great quantities of manufacturing wastes discharged from tanneries and allied industries in both Salem and Peabody, and discharging them into Salem Harbor at a point where they would not cause the pollution of neighboring shores. The works were subsequently constructed in general accordance with the plans recommended, and were completed and their operation begun in the latter part of the year 1906.

Improvement of Neponset River.

By the provisions of chapter 83 of the Resolves of the year 1895 the State Board of Health was directed to investigate the sanitary condition of the Neponset River and the extensive meadows through which it flows in the towns of Walpole, Norwood, Sharon, Canton, Milton and Hyde Park, and to report to the Legislature a plan for the improvement of the river and meadows.

The Neponset River drains an area of about 170 square miles in the southeastern part of Massachusetts, and in the lower part of its course forms the southerly boundary of the city of Boston, finding an outlet into Dorchester Bay in the southerly part of Boston Harbor.

The river, at the time this resolve was passed, was being very badly polluted by sewage, and especially by foul drainage from numerous manufacturing works of various kinds, particularly paper mills, tanneries and woolen mills. In the central portion of its course the polluted river meanders with a sluggish current for many miles through extensive fens, known as the Fowl Meadows, which cover an area of 4,000 acres or more,

much of which is wet or partially inundated throughout the greater part of the year.

The Board reported plans to the Legislature of 1897 both for relieving the river of pollution and for draining the Fowl Meadows, but action upon this matter was delayed until 1902, when a law looking to the prevention of the pollution of the river was enacted. This law was subsequently (in 1906) amended so as to provide a penalty for the pollution of the stream. Since the enactment of this law much of the sewage formerly discharged into the river has been diverted, or is being purified within the watershed, and at nearly all of the manufacturing establishments works have been constructed which provide for the treatment of the manufacturing wastes.

In 1911 an act was passed to provide for the deepening and improvement of the river throughout the Fowl Meadows in order that efficient drainage may be provided for that objectionable area, which has evidently long exercised a deterrent influence upon the growth of population over a very wide area in this region.

Improvement of Green Harbor.

In 1896 the State Board of Health, sitting as a Joint Board with the Board of Harbor and Land Commissioners, was required to consider the question of improving Green Harbor in the town of Marshfield, where it was alleged that, by the construction of a dike reclaiming 1,500 acres of marsh land at the edge of the sea by shutting off a former tidal estuary known as the Green Harbor River, the harbor supplied by this river had been materially damaged and its usefulness largely destroyed.

The Joint Board reported the results of its investigations to the Legislature of 1898, recommending that the dike be retained and the harbor improved and maintained by dredging. The subject of this harbor was again referred to the Joint Board by the Legislature in 1908, and the question again considered.

The Joint Board again reported against the removal of the dike and recommended the maintenance of the harbor, if its continued maintenance should be decided upon, by other plans.

South Metropolitan Sewerage System.

Under the provisions of chapter 65 of the Resolves of the Legislature of 1899 the State Board of Health was directed to consider the general subject of the discharge of sewage into Boston Harbor and the disposal of sewage for the metropolitan districts of the Commonwealth, and to

report a plan for an outlet for a high level gravity or other sewer for the relief of the Charles and Neponset River valleys.

Under this resolve the Board, after investigation, recommended the discharge of the sewage of the Charles and Neponset River valleys — later known as the south metropolitan sewerage district — into the sea at two points north of Peddock's Island in the southerly part of Boston Harbor. The plan was adopted by the Legislature, and the works which were constructed by the Metropolitan Sewerage Commission were completed and first operated in the year 1904. This outlet is located at the bottom of the harbor where the water is 30 feet in depth at low tide, and the quantity of sewage discharged here at the present time amounts to more than 40 million gallons per day.

Improvement of the Sanitary Condition of the Concord and Sudbury Rivers.

The Board was directed by the provisions of chapter 65 of the Resolves of 1900 to investigate the sanitary condition of the Concord and Sudbury rivers and report a plan for their improvement.

These rivers, especially the Sudbury, were being badly polluted by sewage and manufacturing wastes, chiefly by the wastes from woolen mills at Saxonville and Maynard. A plan was prepared for disposing of the wastes from these mills and preventing pollution from other sources and was presented to the Legislature of 1901, but no action has yet been taken.

Discharge of Refuse into Boston Harbor.

In the year 1903 the State Board of Health was directed to report upon the dumping of garbage and rubbish into the harbor and along the seacoast of Massachusetts Bay.

The results of the investigation were reported to the Legislature in 1904, and more stringent regulations on harbor dumping have since been adopted.

Purification of Mystic River and Alewife Brook and their Tributaries.

In the year 1904 the Legislature passed an act requiring the State Board of Health to examine the Mystic River and Alewife Brook and their tributaries and present a report of its investigations with recommendations for purifying those waters and preventing further injury to the public health by reason of the unsanitary conditions existing in the valleys of these streams.

The Board found, as a result of its investigations, that Alewife Brook was badly polluted by sewage and manufacturing wastes and that malaria was prevailing to an alarming extent in the region about the Alewife Brook marshes, an extensive tract of low land lying partly in the cities of Cambridge and Somerville and partly in the towns of Arlington and Belmont, and having an aggregate area of about 1,000 acres. Portions of these marshes were found to be below the level of ordinary high tide, and the Board recommended the construction of a dam across the Mystic River at Cradock bridge to maintain the water at a constant level about 7 feet above low tide, and the enlargement of the channels of the streams and construction of suitable drainage channels in the Alewife Brook marshes to provide proper drainage and prevent the breeding of mosquitoes therein. The prevention of the pollution of the streams was also recommended. The Legislature subsequently provided for the construction of works in general accordance with the plans recommended, and a dam across the Mystic River has lately been completed.

Water Supply of Lynn.

By the provisions of chapter 509 of the Acts of the year 1906, the State Board of Health and the Water Board of the City of Lynn were authorized and directed to investigate plans for enlarging and improving the water supply of that city.

The results of the investigation were reported to the Legislature of 1907.

Improvement and Enlargement of Cemeteries.

By an order of the Legislature of 1907 the State Board of Health was directed to investigate the conditions under which new cemeteries should be established and old ones enlarged. The Board reported the results of its investigations to the Legislature of 1908, and a law was enacted providing for the regulation of the use of cemeteries by local boards of health or by the State Board of Health in cases where cemeteries were to be located within the watershed of any source of public water supply.

Improvement of Lake Quannapowitt and the Lands bordering thereon.

On June 11, 1908, the Legislature directed the State Board of Health to examine Lake Quannapowitt and its watershed and make such recommendations as it might deem expedient relative to the improvement of the low lands about this lake. The Board presented the results of its investigations to the Legislature of 1909.

Merrimack River.

By the provisions of chapter 114 of the Resolves of 1908 the State Board of Health was directed to investigate the sanitary condition of the Merrimack River and report thereon to the General Court.

The results of this investigation showed the need of better regulation of the condition of this river, which had hitherto been exempted from the general laws relative to the pollution of rivers in Massachusetts, and in accordance with the recommendations of the Board presented in its report to the Legislature of 1909, the Merrimack River was included in the laws relating to the prevention of the pollution of streams. By the provisions of another law the Board is directed to report to the Legislature upon the improvement of the river whenever its condition becomes objectionable.

Water Supply of Salem, Beverly and Peabody.

By the provisions of chapter 54 of the Resolves of the year 1911 the State Board of Health was authorized and directed to consider and report on the matter of a water supply for the cities of Salem and Beverly and the town of Peabody taken from the Ipswich River and its tributaries or from any other source or sources that the Board might find available. The results of this investigation were presented to the Legislature in 1911 and 1912.

Lake Cochituate.

Under the provisions of chapter 87 of the Resolves of the year 1911 the State Board of Health and the Metropolitan Water and Sewerage Board, acting jointly, were requested to make an examination of the water of Lake Cochituate and report relative to the protection of the purity of the water. The recommendations of the Board were presented to the Legislature of 1912.

Construction of a Dam to replace the Essex Bridge between Salem and Beverly.

Under the provisions of chapter 84 of the Resolves of the year 1912 the Board is directed to consider and report upon the practicability of constructing a dam at the head of Beverly Harbor, between Salem and Beverly, to improve the sanitary conditions of the North, Danvers and Bass rivers.

Improvement of Shores of Dorchester Bay, Boston.

Under the provisions of Chapter 133 of the Resolves of 1912 the State Board of Health, acting jointly with the Directors of the Port of Boston, is required to investigate the advisability and cost of improving the shores of Dorchester Bay.

B. WORK OF THE STATE HOUSE LABORATORIES AND THE LAWRENCE EXPERIMENT STATION.

At the time of beginning the work of the department of water supply and sewerage, laboratories for the examination of water and sewage were established at the Massachusetts Institute of Technology, and in 1887 an experiment station for investigations in regard to the purification of sewage, filtration of water and allied subjects was established at Lawrence. This station was equipped with filters and chemical and bacteriological laboratories for the proper study of the subjects mentioned. The laboratory force at the Institute of Technology consisted at first of a chief chemist, three assistants, a biologist and bacteriologist with two assistants. The laboratories for water and sewage analysis were continued at the Institute of Technology until 1896, when they were removed to the State House.

The force employed at present at the State House laboratories and at the Lawrence Experiment Station is as follows: —

Chief chemist,	1
Assistant chemists,	11
Bacteriologists,	2
Biologist,	1
Stenographers and clerks,	3
Other assistants,	2

The report of 1887 contained a summary of the work of the water supply and sewerage department in regard to the examination of water supplies, sewage disposal systems, pollution of rivers, etc., and also the first report in regard to the work of the experiment station.

In 1890 two special reports were published. As was stated: —

The general subject of the first volume is the "Examination of Water Supplies of the State," and embraces not only an examination of the water supplies already in use, but also of the rivers and of many available sources of supply not now in use.

The topography of the Commonwealth is peculiarly fitted for this comprehensive study, embracing, as it does, waters of varying character, from the

more highly colored waters of the marshes and bogs of the low lands, to the clearer waters of the Berkshire hills, including the polluted waters of thickly settled regions and the unpolluted waters of uninhabited regions.

This volume contained descriptions of the water supplies of the State, embracing 135 supplies furnished to cities and towns and public institutions. It also contained the results of analyses of these water supplies. Certain sections of this report dealt with the classification of water supplies, interpretation of analyses and discussion of special topics. The topics discussed were as follows: —

The distinction between normal and polluted waters.

The chemical evidence of pollution in waters.

Normal chlorine.

The idea of permanence and of various degrees of susceptibility to decay in organic matter in water.

The absence of dissolved oxygen, and the putrefactive changes of organic matter in some waters at considerable depths.

The effect of growing plants in obliterating evidences of decay.

The chemical evidence of bacterial action in the state of change of organic matter.

The essential differences in character of surface and ground waters which influence the interpretation of analyses.

The influence of the season of the year on the composition of surface waters.

The discussion of "Special Topics relating to the Quality of Water Supplies" contained much information of a practical bearing upon the selection of sources of public water supply and the methods of storage both of ground and of surface waters.

Special prominence was given to the effect of storage upon the color, taste and odor of water, as well as the chemical composition.

A portion of this section was devoted to the investigation of the character of the water in deep ponds at different depths and at different seasons of the year.

Studies were made of the organisms which caused serious annoyance from their periodical development in certain supplies, and a general statement was made of the results and observations upon the natural filtration of water in several places in the State.

An important chapter was entitled "The Pollution and the Self-purification of Streams." This contained a summary of observations upon the condition of some of the principal streams of the State, large and small, into which sewage was continuously discharged.

The second special volume published in 1890, contained the methods and results of the experimental investigations of the Board up to that date upon the purification of sewage by filtration and by chemical precipitation, and upon the intermittent filtration of water made at the experiment station at Lawrence. The report gives a description of the experiment station and states the object of the work, namely: "to determine the fundamental principles of filtration not previously established, and to learn what can practically be accomplished by filters made of some of the widely varying material found in suitable localities for filtration areas, that there may be deduced from these results, together with the quality and physical characteristics of the materials used, the probable efficiency of other materials to be found throughout the State."

The report stated also that "while deductions are fully made in the light of this beginning of the science of filtration, all of the data of chemical and biological analysis, and, as far as may be, the attendant circumstances, are recorded, that they may serve the future student as the means of verification or of correction in the greater light which further investigation may give him."

It was stated that "in the presentation of these results, and their discussion, many additions to the knowledge of the world upon this important subject of purification of sewage by filtration are given."

Both of these reports dealt with new phases of sanitary science never until this time taken up in such a thorough, scientific and comprehensive way as they were then being investigated by the Board.

The experiment station, started in 1887, is still in operation, and the work there up to the present time has covered a period of twenty-five years. In the chemical and bacteriological laboratories of the station more than 50,000 chemical and 150,000 bacterial analyses have been made. New and more accurate chemical, biological and physical methods have been developed for the study of water, sewage, sands, soils, etc. Beginning with studies upon intermittent sand filtration of sewage and water, together with laboratory investigations upon nitrification, the causes of the reduction of bacteria by filtration, etc., the work of the station has grown constantly and has included experimental investigations tending towards the development of scientific methods of sewage purification, of the purification of manufacturing wastes of many kinds and many other special investigations in sanitary science.

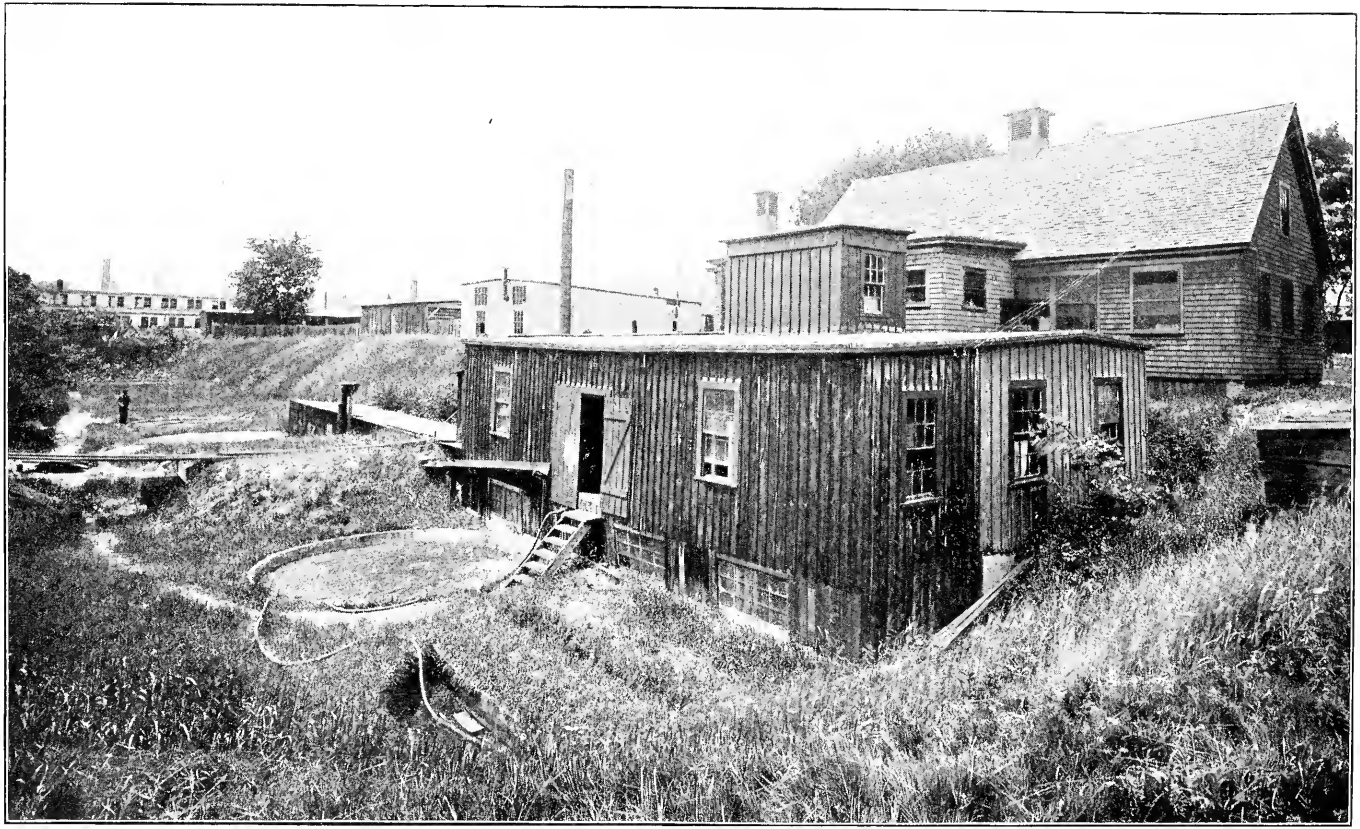
The experiment station report for 1891 took up the subjects of permanency of filters, the mechanical composition of materials used in filters, together with the conclusions drawn from a study of the materials and the results of filtration, as showing the capacity of each material to

purify sewage; the best method of applying sewage to different grades of sand, etc., together with further experiments on the bacterial efficiency of the filters at that time in operation. Early in this year a gravel filter was operated at a rate of 220,000 gallons per acre daily, the sewage being applied in 60 or 70 doses per day. Good nitrification results were obtained without artificial aeration of the filter; in fact, this was a true trickling filter as now known.

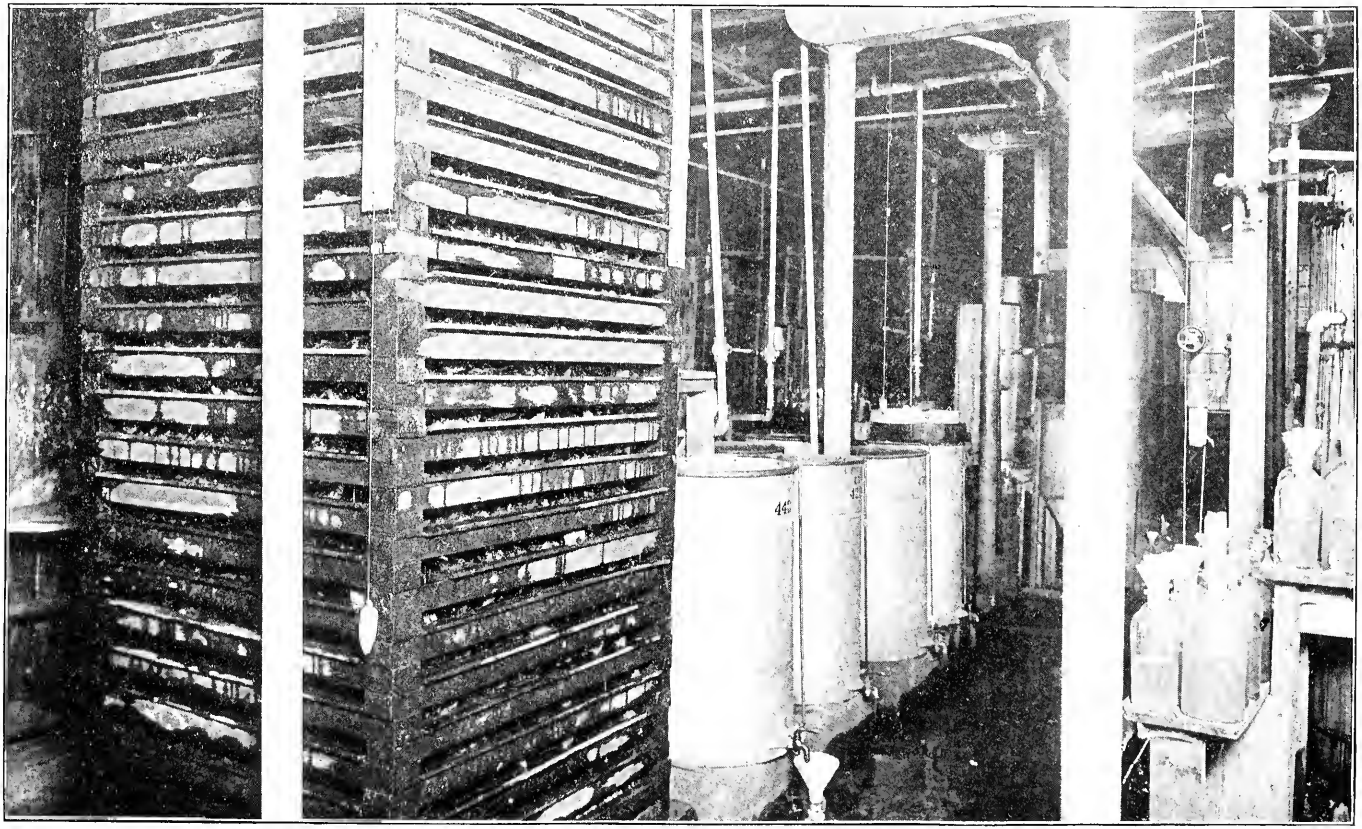
In 1892 and 1893 special studies were made of the care of sewage filters; stratification and the effect of horizontal layers; filtration of sewage containing dyestuffs; the rate of filtration through various materials; the causes of clogging of sewage filters; and the removal of this clogging matter from the sand. In these years, also, studies of rapid filtration aided by artificial aeration of the filters were begun. The report for 1892 contained, in addition, a very important article upon the physical properties of sands and gravels with special reference to their use in filtration.

In 1894 a general review of the work upon sewage purification at the station up to and including that year was given. Special investigations were made at that time upon the composition of sewage and the changes which occurred in sewage as it ages. It was shown, for instance, that storage of fresh Lawrence sewage for twenty-four hours doubled the free ammonia and decreased the organic nitrogen present one-half. Other changes, such as an increase in the number of bacteria present, also took place. This work antedated the operation of septic tanks. At this time a series of sewage samples were collected at different periods of the day from various sewage-disposal areas and institutions in the State, and were examined to show the varying strengths of the sewage at different hours and the amount of organic matter of different kinds in the sewage per person contributing to the flow.

In 1895 investigations were continued as to the best methods of treating sewage filters to insure permanency; on the best preliminary treatment of sewage to remove sludge before filtration and the different methods of aerating sewage filters. In this year, also, were made the first experiments upon the purification by filtration of industrial sewage as discharged from tanneries, paper mills, wool-scouring works, etc. The stable character of the effluents from trickling filters operated at high rates, and aerated a portion of the time by means of a current of air, was first shown at this period. It was found that "the organic matter in the liquids, after rapid filtration combined with aeration, is of a different character from the organic matter in the sewage resulting from other sludge-removing processes; that is to say, even when the organic matter, as shown by the albuminoid ammonia, is present in quantities as



Lawrence Experiment Station. Exterior.



Lawrence Experiment Station. Interior.

great as in the other partially purified sewages, it has passed through such chemical and biological changes that it develops offensive odors very slowly on standing." These observations were made prior to the English studies upon the stability of the effluents of such filters. In this year, furthermore, certain filters of coarse materials, gravel-stones, pieces of coke, etc., were operated at rates of 1,000,000 gallons per acre daily, and were aerated generally only from one to two and one-half hours daily. The effluents of these filters contained high nitrates, were generally stable, and, in fact, were practically similar to those afterwards obtained from filters of like materials operated at high rates without even the slight aeration given to these filters.

In 1896 and 1897 much time was devoted to the study of the purification of industrial sewage, and practicable methods for the purification of some of these wastes are definitely described in the reports for these years. From the first, studies looking to the removal of the matters in suspension in sewage by sedimentation, chemical precipitation and coke straining were made. In 1897 more elaborate experiments were begun on the purification of sewage by so-called contact filters, although one such filter had been studied at the station in 1894. During this year (1897) a trickling filter of clinker was operated also. To this the sewage was passed by means of overhead pipes and was aerated and distributed by the dash-plate method. This trickling filter, and all others started after this date, received no artificial aeration.

In 1898 studies were continued on the disposal of sewage, both fresh and stale, when treated in septic tanks; on the purification of industrial sewages; on the purification of sewage both by sand and contact filters. Early in 1899 there was put into operation a trickling filter 10½ feet in depth, constructed of broken stone and operated at a rate of 2,000,000 gallons per acre daily. In 1899, also, studies of septic tanks and of the purification of septic sewage were continued, and the first tank for the treatment of sludge alone, after preliminary sedimentation of the sewage in ordinary settling tanks, was put into operation and continued for several years. This variety of septic tank and method of sludge disposal has since become well known. The first hydrolytic tank was started also at the station in 1898. "As it had become evident that the greatest work in septic tanks occurred where the bacteria were most numerous, — as on the sides, bottom and top of the tank, — it was considered that a tank filled with coarse, broken stone would afford a very extensive foothold and breeding place for the classes of bacteria necessary for sludge disposal," and the tank was so arranged that the sewage passed upward through this stone. As the result of other researches it was shown that prolongation of anaerobic action might impede subsequent

purification by filtration. There were made also this year special studies relating to the purification of the wastes from creameries, and to the action of iron and iron oxides on the purification of sewage by filtration.

In 1900 analyses and measurements of the gas produced by septic tanks were made and investigations concerning the efficiency of septic treatment of different classes of sewage; also experiments upon the sterilization of septic sewage, to show whether or not the air that it was necessary to introduce into some classes of sewage, before efficient purification by filtration could be assured, was required because of the rapid use of the oxygen by bacteria or because of its absorption by organic matter and gases. During this year the method was first elaborated at the station to show the oxygen absorption powers of sewage, this method being fundamentally simply the mixture of certain volumes of sewage with water saturated with dissolved oxygen and determining the oxygen consumed or absorbed by the mixture during certain definite periods. The operation of the hydrolytic tank, together with various trickling filters, and the study of purification of manufacturing wastes were continued.

In 1901 a thorough investigation was made of the stability of the effluents and of the organic matter left in the effluents of contact and trickling filters, together with observations on the improvement of such effluents when mixed with river water. The rate and degree of clogging of materials were studied also. In this year contact filters of roofing-slate and brick, with regular spaces between each pair of slates or bricks, were first put into operation. Two of these filters are described in the report for 1901, the slate filters being similar to those operated in more recent years in England by Dibdin.

In 1902 studies of contact and trickling filters, especially those of the latter, were continued, together with special investigations concerning nitrification and the removal of organic matter from the upper layers of sand filters.

In 1903 special efforts were made to learn the cause of the poorer winter nitrification in the older intermittent sand filters, in order to improve the work of these filters. Studies of septic tanks and of the operation of contact filters constructed of different materials and depths, with special regard to permanency of operation, were continued, together with allied studies upon the stability of their effluents. Studies were made also of the purification of sewage by trickling filters of different materials and different depths, and investigations in regard to the stability of the effluents of these filters and experiments upon sedimentation, secondary filtration, etc., of these effluents were undertaken. Numerous experiments were made on the purification of dye liquors and the waste

from gas works, together with studies on methods of analysis with special regard to the comparative value of albuminoid ammonia and Kjeldahl determinations of nitrogen; of incubation of effluents; and of the nitrification and denitrification caused by sand, effluents and species of bacteria from filters in which either nitrification or reducing actions were occurring.

The year 1904 was devoted largely to the improvement of the sand filters that had been in operation for sixteen years, and to studies of methods for the disposal of nitrogenous and other organic matters by these filters; special studies of nitrification; studies of the respective amounts of nitrogen and carbon oxidized, stored or liberated from experimental and municipal sand filters; studies of the determination of acidity or alkalinity as an index of the degree of purification of filter effluents; studies of the bacteriology and biochemistry of sewage purification. A new method for the determination of turbidity of the effluents of filters and of water was developed and first used during this year. Studies were made also of the time of passage of sewage through trickling filters constructed of different materials and of different depths, and of the rapidity of oxidation and purification of these filters.

In 1905 a continuation was made of the studies of the organic matters, nitrogen, fats, carbon, etc., in sludge and in sewage, and of the same substances stored in filters; studies of the relative amounts of nitrogen, carbon and fatty matters in sewage, sludge and the effluents of trickling and contact filters and appropriate methods for their analysis. Moreover, special studies were taken up again as to the refiltration of trickling filter effluents through sand filters.

In 1906 a complete résumé was given of the comparative value of sand, contact and trickling filters for the disposal of organic matter, and the comparative rates at which such filters can be operated; of the rate of filtration and amount of suspended matter in sewage applied to sand filters as related to volume of sand removed; of the coagulation and mechanical filtration of the effluents of trickling filters, together with more complete studies of methods for the application of sewage to trickling filters; of the comparative rates of filtration maintained by sand filters; of continued studies on the purification of industrial wastes.

In 1907 the most important special work was a continued study of methods for the distribution of sewage upon trickling filters and observations on the refiltration of trickling filter effluents through sand, together with studies of coagulation and mechanical filtration.

In the report for 1908 a complete review was given of all the investigations made at the station up to that time upon the purification of domestic sewage, and the report for 1909 contained a review of all the

work done by the Board upon the purification of factory wastes. During 1910 and 1911 special studies were made upon the influence of carbon upon nitrification, the disinfection of sewage and the effluents of sewage filters and upon the determination of the character and strength of sewage by the oxygen absorption powers.

During all the years these investigations in regard to the purification of sewage, manufacturing wastes, etc., have been carried on, experiments have also been made in regard to all phases of the purification of water, and in this period about 100 filters have been operated in connection with such studies. The filters at first were composed of fine sand, loam, etc., but as the studies progressed, sands of coarser material were used and thorough studies made in regard to the chemical and bacterial purification of polluted waters when filtered through these sands at various rates.

One of the early results of the Lawrence studies was the construction of the municipal filter of the city of Lawrence, the first large sand filter plant in this country. The work of this filter has been followed, and it was found during the first years of its operation that not only did it materially reduce the cases and deaths from typhoid fever in the city of Lawrence, but that the general death rate from all causes was also materially reduced. This fact has been widely quoted and studied by others in connection with other filtration systems.

Studies in regard to the purification of water containing iron were carried on in 1896, and an article in regard to this subject was published in the report of the Board for that year.

The report for 1897 contained a résumé of the work upon the purification of water carried on during previous years in which all the factors affecting the efficiency of water filters, such as fluctuations in rate, scraping of the surface, depth of sand, etc., were summarized.

Previous to 1897 numerous tests had been made on the hygienic efficiency of various water filters by applying to them from time to time cultures of B. prodigiosus, but beginning in 1896 tests for B. coli, which had been investigated previously, were extended and the waters applied to, and the effluents from, all the filters of the station were examined in this way. This was the beginning of the use of the B. coli test for the examination of water supplies, especially for filtered waters. Such tests are now universal in all laboratories where similar work is carried on.

The report for 1898 contained an article describing the methods for determining B. coli. In 1899 studies of double filtration of very polluted water were continued, and also elaborate studies made in regard to the removal of color, tastes and odors from water. This report con-

tained also a review of the work upon filters operating intermittently and continuously, with data as to the comparative efficiency of such filters when filtering water such as used in the experiments described.

In 1900 extensive examinations of the spring waters in the State were carried on, and the first work upon the examination of shellfish from polluted and non-polluted sources was done. In this report also was an article in regard to the bacterial purification of water by freezing, and an article in regard to the efficiency of water filters in removing different kinds of bacteria, the significance of B. coli in filtered waters, and the relative removal of B. coli and typhoid bacilli by water filters.

In the report for 1901 an article was given describing the results of studies made in regard to the removal by filtration of microscopical organisms, tastes and odors from a surface water supply in the State, highly colored and rendered offensive in odor by extreme growths of such organisms.

The reports for all the years subsequent to this up to the present time have contained much data in regard to the purification of waters of different classes; the effect of turbidity upon the operating results of water filters; the relative occurrence of B. coli in waters of different kinds, in ice, shellfish, etc.; and the significance of the various types of bacteria used, or that can be used, to show pollution; and in regard to the relative length of life of B. coli and the typhoid bacillus under a wide variety of conditions.

In 1903 experiments were begun which have been continued up to the present time in regard to the purification of polluted waters by so-called mechanical filters, that is, by filtration through a filter of coarse sand operated at a high rate with the aid of sulphate of alumina or some other like chemical as a coagulant, and much data have been given in the reports to show the chemical and bacterial efficiencies of such filters when operated at rates varying from 25,000,000 to 125,000,000 gallons per acre daily, and with varying amounts of sulphate of alumina or similar coagulants.

In the year 1904 extensive studies were made and reported in regard to the use of copper sulphate as a germicide in water purification, and of the influence of copper sulphate in water upon the subsequent purification of such water by sand filtration. Other studies in regard to the purification of water by disinfection with such chemicals as copper sulphate, bleaching powder, etc., have been given in different reports. In fact, the variety of work in regard to the purification of water has been so great, and the number of investigations carried on at the station in regard to the purification of water has been so large, that only a partial summary of the work can be given here.

At the State House laboratories 102,000 chemical and 55,000 microscopical analyses have been made up to the present time, all this work being necessary on account of not only the first act of the Legislature, passed in 1886 in regard to the protection of the purity of inland waters, but on account of the many other acts and resolves of the Legislature placing special investigations in regard to sanitary affairs of the State in the hands of the State Board of Health.

4. DISEASES DANGEROUS TO THE PUBLIC HEALTH.

The Legislature of 1907 authorized the State Board of Health to declare certain diseases as dangerous to public health, and requiring that householders and physicians give immediate notice to the local board of health of all such cases, which must be reported by the local board of health to the State Board of Health within twenty-four hours.

The list of diseases at present reportable under the law are: —

Actinomycosis.
Anterior poliomyelitis.
Asiatic cholera.
Cerebro-spinal meningitis.
Diphtheria.
Glanders.
Leprosy.
Malignant pustule.
Measles.
Ophthalmia neonatorum.
Scarlet fever.
Smallpox.
Tetanus.
Trachoma.
Trichinosis.
Tuberculosis.
Typhoid fever.
Typhus fever.
Varicella.
Whooping cough.
Yellow fever.

The activities of the Board as far as communicable diseases are concerned are along three distinct lines: —

1. Making bacteriological examinations for diagnosis and release of patients.

2. Investigating sources of infection.

3. Free distribution of sera, vaccines and other prophylactic agents.

(1) *Bacteriological Examinations.* — In 1895 a laboratory for the examination of suspected material was established by the State Board of Health to aid in the diagnosis of diseases dangerous to public health. This laboratory is free to all the physicians in the State. Examinations are made of cultures for diphtheria organisms, of sputa and other material for tubercle bacilli, of blood for malarial organisms, of blood for the serum reaction of typhoid, of blood, urine and stools for typhoid organisms. Outfits for obtaining the suspected material are furnished by the Board.

(2) *Investigating Sources of Infection.* — The State Board of Health through its State Inspectors of Health watches the incidence of communicable diseases in each city or town, makes thorough investigation of

the source of infection of any outbreak, and circulates information as to the best measures of preventing the spread of communicable diseases. Since 1907 special annual appropriations are made by the Legislature for the investigation of poliomyelitis in the State, and extensive epidemiological studies of the disease are published annually.

(3) *Free Distribution of Sera, Vaccines and Other Prophylactic Agents.* — The State Board of Health distributes free of cost diphtheria antitoxin, smallpox vaccine, and a prophylactic solution of silver nitrate for ophthalmia neonatorum. Preparations are being made for the free distribution of antimeningitis serum and antityphoid vaccine.

5. THE ANTITOXIN AND VACCINE LABORATORY.

The discovery by Behring of the antitoxic power of the blood in animals treated with diphtheria toxin, and the successful attempts of Behring, Roux and others to produce antitoxin on a large scale, led Dr. H. P. Walcott, chairman of the State Board of Health, in 1894, to consider the advisability of establishing a laboratory for the production and free distribution, under State supervision, of this preventive and curative serum.

There might have been at that time, in the minds of some of those interested in the public welfare, reasonable doubts of the desirability of this new departure but, viewed from the standpoint of to-day, this plan has proved to be eminently wise and the undertaking fully justified. We need simply to consider the price of antitoxin to-day to be convinced of the advantages of an economically managed State institution in supplying those quite unable to pay for the serum.

In the autumn of 1894 the preparation of antitoxic serum was begun tentatively by Dr. J. L. Goodale, in a laboratory of the State House. The horses were kept in a stable on the grounds of the Bussey Institution of Harvard University, near the Forest Hills station. Some serum was distributed as early as the spring of 1895. At that time Dr. Theobald Smith fitted up a number of laboratory rooms in the Bussey Institution, and took charge of the work as soon as the laboratories were ready, in the early summer.

For a period of nine years the preparation of diphtheria antitoxin was carried on in the Bussey Institution under the personal direction of Dr. Smith. This close supervision was made possible by the establishment of the chair of comparative pathology in the Harvard Medical School, through the munificence of Mr. George F. Fabyan. The laboratory connected with this department was practically coextensive with that of the serum laboratory, and permitted that co-operation which enabled Dr. Smith not only to direct the routine work, but also to engage in investigations directed towards the improvement of the serum and the greater accuracy of standardization.

With the increasing demand for serum, culminating during the epidemic of 1900–01, the quarters in the Bussey Institution became more and more inadequate, and it was evident that the time had come for the State to take cognizance of this eminently philanthropic work by providing more appropriate quarters, and placing the preparation of diphtheria antitoxin on a more stable basis.

At the same time another problem was brought forward, which involved the preparation and free distribution of vaccine lymph by the State Board of Health. The importance of some direct supervision and control of this prophylactic substance by the State had been felt for a long time, but any supervision of a product made largely outside of the State and by a number of different parties was impossible. The only solution was the assumption by the State itself of the preparation of the lymph, as is the practice in nearly all European countries.

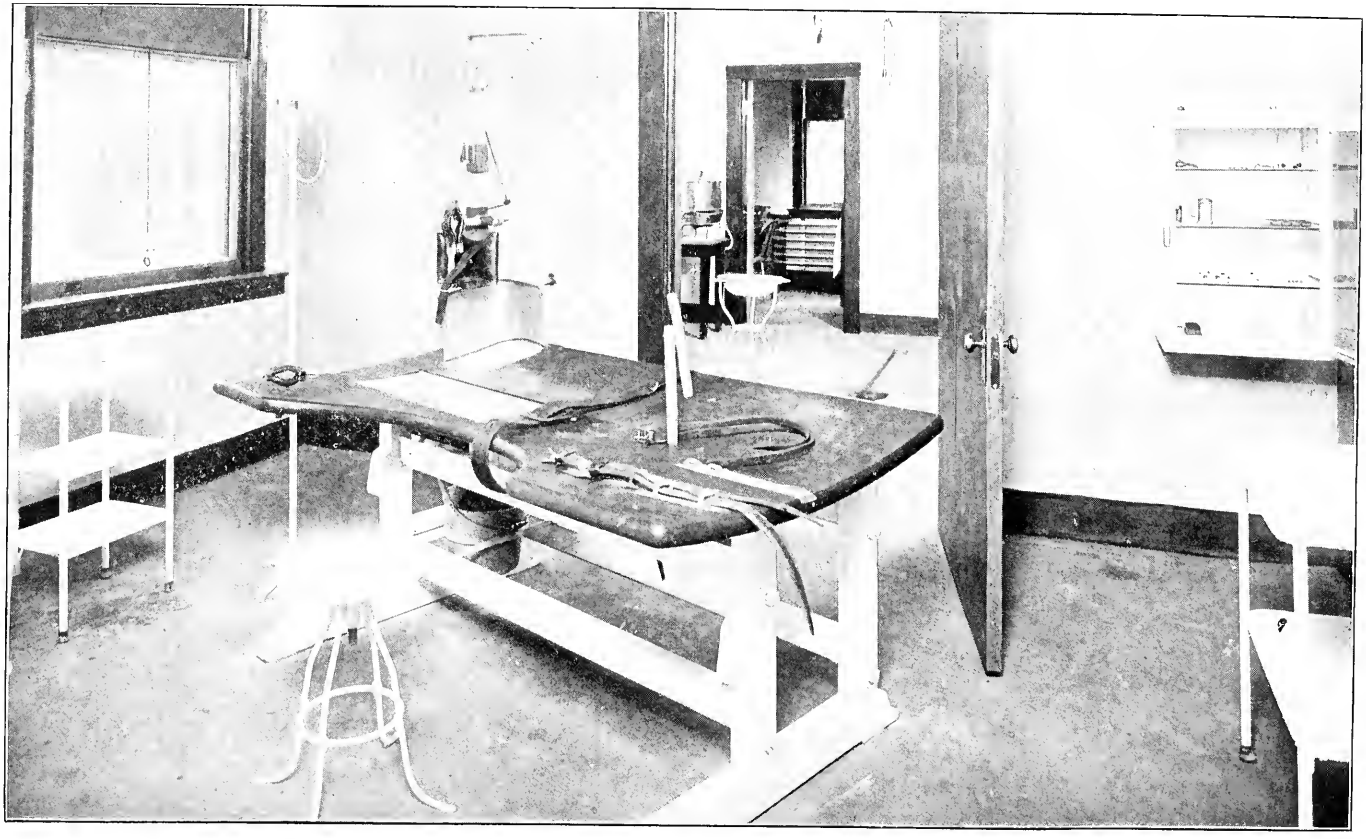
During the session of 1903 the Legislature finally passed a bill which authorized the State Board of Health to produce and distribute antitoxin and vaccine lymph.

To obtain a suitable site for a State laboratory, free from objectionable surroundings, with sufficient land about it to secure light and air, and not subject to the complaints or the objections of fastidious neighbors or sensitive real estate owners, would have been impossible without acquiring a large and expensive tract.

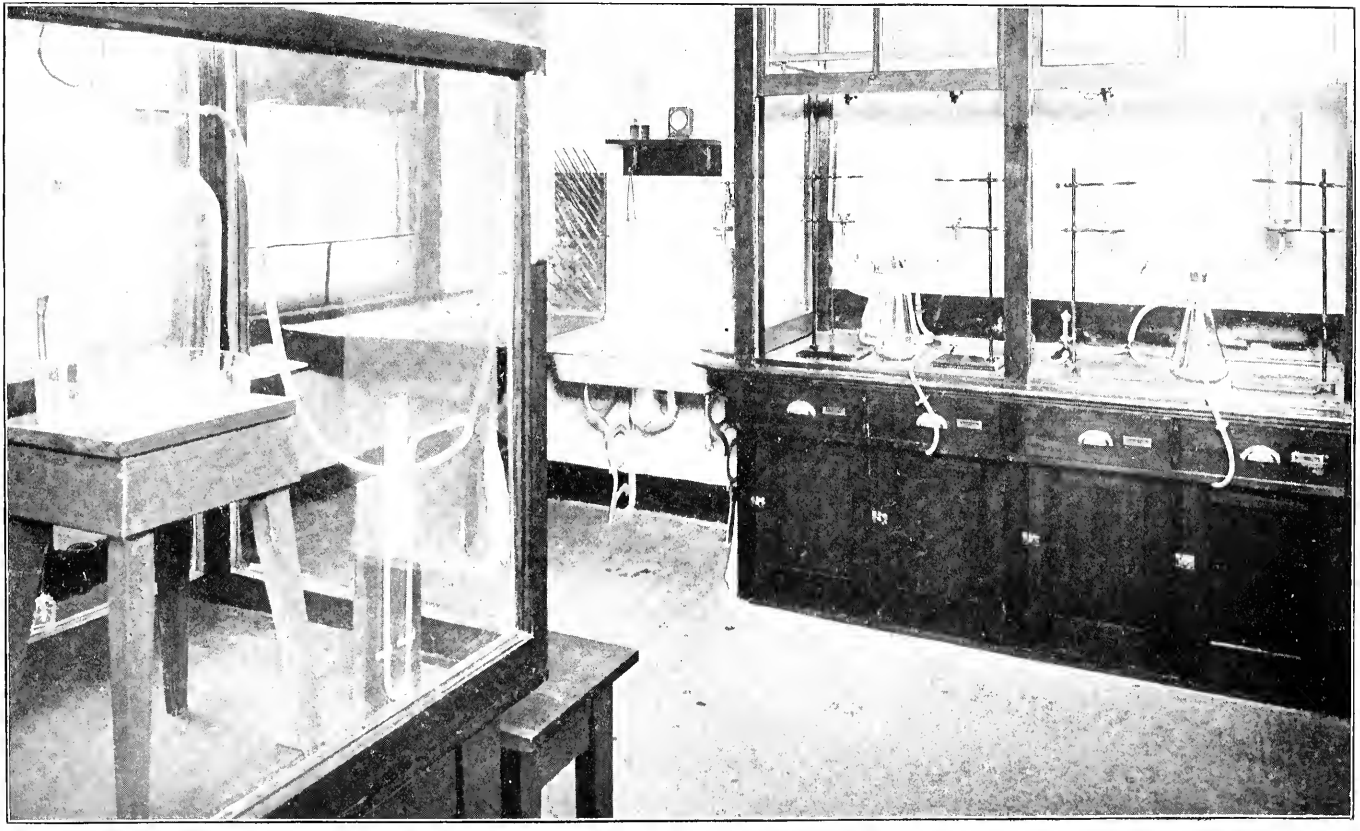
To overcome this difficulty, the Corporation of Harvard University came to the aid of the State, and agreed to use a portion of the land of the Bussey Institution adjoining the Arnold Arboretum, and build a laboratory in which the preparation of diphtheria antitoxin and animal vaccine could be carried on together. After the passage of the bill authorizing the State Board of Health to prepare diphtheria antitoxin and vaccine, Dr. Smith visited a number of vaccine institutes in England, Germany, France and Denmark during the summer of 1903. In the fall of the same year the site for the new building was selected, the plans made and the building begun. On account of the very severe winter of 1903 and 1904, building operations were almost wholly suspended until late in March. However, the work progressed uninterruptedly in the spring, and the building was ready for occupation in July. The production of antitoxin continued without interruption in the old laboratory during the installation of apparatus in the new. The production of vaccine was begun in July, and late in September the first lot was issued.

The building is situated on South Street, about one-quarter of a mile beyond the Forest Hills station of the New York, New Haven & Hartford Railroad. It faces slightly east of south, and receives an abundance of sunshine, as no shadows from other structures fall upon it. The windows have been constructed amply large to admit plenty of light. The situation is ideal, as the building stands in a park reservation of over 200 acres of land.

The building is nearly square, and has an extension or wing consisting of basement and first floor only. This wing was designed to house the calves after vaccination. The floors are of cement in the basement, of



The Operating Room for Calves.—Antitoxin and Vaccine Laboratory.



Antitoxin Filtering Room.

Antitoxin and Vaccine Laboratory and Stable.

cement covered with a layer of asphalt in the remainder of the building. The walls and ceiling are covered with a very hard plaster, and painted with enamel paint to give a smooth surface, easily washed and disinfected. The doors are covered with tin and heavily painted, and fit into iron frames. The structure is thus nearly fireproof. It is lighted by electricity.

In planning the arrangement and division of the interior for the production of diphtheria antitoxin and animal vaccine, the experience in the preparation of antitoxin, covering a period of nine years, and an extensive investigation of existing vaccine plants of this country and Europe were used as a guide.

The basement consists of a room used as a receiving room, where apparatus, supplies, etc., are unpacked; a room for guinea pigs, rabbits, mice, etc., used in the testing of antitoxin and vaccine; a vault with double brick walls, in which the serum and vaccine are stored; a storeroom which contains the hot-water plant for the heating of the building; and a general storeroom.

The first floor consists of the director's room, which is also used for the storage of valuable apparatus; a document room, which provides desk room for assistants; a room for the cleaning and sterilizing of all the glassware used in the building, which also contains a large autoclave in which culture media, milk, hay, etc., are sterilized; one room is set aside for the testing of serum and vaccines, and for other operations on small animals. The remainder of this floor, including the wing, is set apart for the production of vaccine. These animals are driven up an incline in the rear of the wing to a room where they are thoroughly washed and then placed in an adjoining room which is fitted up as an incubation stable; *i.e.,* the place where the animals are kept during the development of the vaccinal eruption. This stable has windows facing northeast and southwest, and receives abundant sunshine. The floor is concrete, covered with asphalt. The walls of this stable are finished like those of the other parts of the building, and they can be easily washed and disinfected.

This floor also has an operating room. Here the calves are fastened to the operating table, shaved and vaccinated and returned to the stable. After a certain number of days (four to six) the calves are returned to the table and the vaccinal eruption removed.

Adjoining the operating room is a room fitted up like the stable, to be used for calves in case of emergency. It has a special entrance. It is ordinarily used for sterilizing water and the instruments and gowns used during the operations on calves.

The second floor consists of a room set aside for the filtering and bottling of diphtheria antitoxin; a room for the grinding of vaccine and

for filling it into tubes; and a room in which all culture media are prepared. One large single room is set aside for bacteriological and other work incidental to the preparation of diphtheria toxin and the bacteriological testing of vaccine. For this purpose a little room has been set aside as a place free from drafts and dust. Lastly is a small room on this floor where the vaccine is packed for distribution.

It will be seen that the building has been arranged quite exclusively for the routine preparation of the products authorized by law. Any extensive investigations are not to be undertaken here, as no space has been set aside for this purpose. For minor investigations, looking towards the steady improvement of the products, there are ample facilities, however. In deciding for this plan, Dr. Smith had in mind the safeguarding of the products. By banishing bacteriological work not immediately bearing upon the problems of antitoxins and vaccines, the latter are not likely to become infected.

Since the establishment of the laboratory, there has been a marked increase in the strength of antitoxic serum. That which was regarded as of quite satisfactory concentration in 1895 would be rejected at present. This improvement was due chiefly to advances in the methods of producing concentrated toxins, coupled with the discovery of races of bacilli which produce far more than the average amount of toxin in culture fluids. It was furthermore due to the elimination of horses which under any treatment produce but little antitoxin. By a careful selection of horses and the use of a concentrated toxin for immunization, sera of very great potency have been obtained. These are, however, exceptional, since only a very small percentage of horses produce sera of high potency.

Parallel with the increase in the strength of the serum produced, there has been a corresponding improvement in the method of testing this strength. With these improvements there has steadily risen the amount of antitoxin used in the treatment of diphtheria. While a dose of 1,000 units was recommended as sufficient in 1895, the initial dose commonly used at the present time is 3,000 units.

For the production of diphtheria antitoxin the number of horses required has fluctuated from 8 to 24, according to the season. As there are, up to the present, no characters known between a good and a poor antitoxin producer, the horses obtained by purchase are all subjected for two to three months to the usual process of immunization, which consists in the periodical injection under the skin of increasing doses of diphtheria toxin. If, after this preliminary treatment, a test of the serum falls below a certain level, the horse is rejected, and a new one

put in his place. A considerable item of expense has been the great increase in the cost of horses.

The total distribution of antitoxin since 1895 and the continual increased demand for the serum can be seen in the accompanying table: —

	Bottles.
In 1895–96 (year ended March 31),	1,724
In 1896–97 (year ended March 31),	3,219
In 1897–98 (year ended March 31),	4,668
In 1898–99 (year ended March 31),	12,491
In 1899–1900 (year ended March 31),	31,997
In 1900–01 (year ended March 31),	53,389
In 1901–02 (year ended March 31),	40,211
In 1902–03 (year ended March 31),	33,475
In 1903–04 (year ended March 31),	41,133
During six months ended Sept. 30, 1904,	22,255
In 1904–05 (year ended Sept. 30, 1905),	47,387
During fourteen months ended Nov. 30, 1906,	70,424
In 1906–07 (year ended Nov. 30, 1907),	64,807
In 1907–08 (year ended Nov. 30, 1908),	94,645
In 1908–09 (year ended Nov. 30, 1909),	90,131
In 1909–10 (year ended Nov. 30, 1910),	92,623
In 1910–11 (year ended Nov. 30, 1911),	96,522
Total,	801,101

The production of vaccine lymph on a large scale has become necessary in the struggle of a dense population against such a pervasive virus as that of smallpox. Isolation does not succeed in itself alone to suppress an outbreak. The need for individual protection conferred by vaccine lymph had been fully appreciated by the medical profession during the nineteenth century. Hence the law in this State that children cannot enter the public schools without this protection.

The success of the public sanitary organization in promptly isolating cases of infectious disease has led the public in recent years to regard the value of vaccination as a protection against smallpox with more indifference than our forefathers, who did not have boards of health and other sanitary organizations ready at a moment's notice to seize the first case and isolate it in smallpox hospitals. Abetting this indifference is a widespread fear among the more intelligent of the laity of the dangers of vaccination. This fear is chiefly an heirloom of former generations, when human vaccine lymph was used almost exclusively, and when certain human infections were occasionally transmitted in the lymph.

The use of carefully prepared and previously tested animal vaccine to-day should not give rise to any difficulties, unless the operation be carelessly performed, or the wound not properly protected from subsequent infection. If the lymph is prepared without proper precautions it may give rise to various local troubles, due to the presence of miscellaneous bacteria, in spite of the care exercised during and after vaccination.

It being the attitude of the State that individuals living within its borders should possess vaccinal immunity, and that this is best accomplished by vaccinating the young, the duty of the State in providing a safe and efficient vaccine lymph is self-evident. To exercise supervision over a number of vaccine plants in and out of the State being impossible, the only alternative is the assumption by the State itself of the responsibility of preparing and distributing vaccine. Furthermore, it is the only way to bring the physician who performs the vaccination in close touch with the producing laboratory. It eliminates the various middlemen, in whose hands the vaccine is likely to deteriorate.

Vaccine differs essentially from diphtheria antitoxin; in fact, there are hardly any points of similarity, beyond the one that both are inoculated into human beings. This, however, is the focal point of the whole matter, and every step in the preparation must be regarded from the standpoint of its use upon human beings, and more particularly children. It is the use of various checks and safeguards which controls the entire process and probably doubles or triples the final cost. Vaccine differs from antitoxin in its perishable quality. Although certain strains of vaccine kept in the cold may still be very active after seven or eight months of storage, others may be inactive after three or four months. This is not the case with diphtheria antitoxin, which remains practically unchanged for six months, and thereafter loss of antitoxic power proceeds very slowly.

Again, antitoxin is prepared at the outset free from bacteria or other micro-organisms. This is not possible in the preparation of vaccine lymph. The development of the vaccinal eruption on the surface of the calf's body, the presence of exudations, the slight formation of crusts, favor certain ordinary bacteria of the skin, and the fresh lymph always contains bacteria. These, however, coming from the calf, have been shown by many investigators to be harmless to man. They are probably far less harmful, and are present even in fresh lymph in much smaller numbers, than those in the milk we drink on a summer's day. No one would be very much exercised over the operation of slightly scratching the skin and placing on the scratch a drop of milk: and yet this operation would be far more serious, from a bacteriological standpoint, than

the introduction of vaccine lymph, so far as the bacterial content is concerned. This illustration serves to point out our indifference to daily occurrences, and our apprehensions towards those that occur but once or twice in our lives.

In the preparation of diphtheria antitoxin the laboratory equipment is more detailed than in the preparation of vaccine. It presupposes much more technical training, and cannot be undertaken except by well-trained medical bacteriologists. With vaccine the conditions are somewhat different. Any one who has witnessed the production of vaccine may prepare it in an old cow stable, and some room where it can be put up for distribution. No technical knowledge is required, beyond ability to recognize the character of the eruption. Yet the preparation of such vaccine would be bare of all safeguards devised by modern medical science. It is the fundamental simplicity of the process which has induced many in the past to try their hand at making vaccine lymph.

To-day its preparation demands, among other things, the inspection by immediate autopsy of the health of the calves used for vaccine; the absolutely clean, aseptic condition of the incubation stable, and the sterilization of the feed of the animals used; general surgical asepsis in the operation of inoculating the animal and in removing the vaccine; the aseptic handling and sealing of the lymph; the removal of the bulk of the bacteria in lymph either by storage at low temperature for six to eight weeks, by carbolic acid or chloroform; and, finally, the testing of the vaccine on small animals and at intervals by bacteriological methods. These are all precautionary processes, based on modern medical bacteriology, which have nothing to do with the essential production of vaccine. They simply hedge in by safeguards the process itself. The use of these safeguards makes it impossible for any but trained bacteriologists to direct the process, and demands laboratories and stables of special construction.

It is of considerable interest to note that vaccine dispensed by different institutes is not derived from one and the same stock. There are three sources available: —

1. The virus descended from spontaneous cowpox, and continued through an indefinite series of animals, — the true animal vaccine.

2. Virus obtained from animals which have been inoculated with lymph from human vaccine pustules, either directly or indirectly, through a series of calves. This is known as retro-vaccine.

3. Vaccine obtained by passing smallpox virus through the cow, — the so-called variola-vaccine. During repeated passages through the cow the smallpox virus is profoundly altered, and converted into the relatively harmless vaccine virus.

It would probably be impossible for many vaccine plants to trace the genealogy of their current stock back to its beginning. In Germany the use of lymph from the arms of children (retro-vaccine) has been a favorite mode of rejuvenating impaired animal virus.

An inspection of a considerable number of vaccine laboratories in Europe and some in our own country revealed the fact that each institution followed to a certain extent methods of its own. The general underlying principles were the same, for in all cases the end product was glycerinated pulp, *i.e.,* the vaccinal eruption removed with a curette and ground up into a fine suspension with diluted glycerine. The procedures for obtaining this end product differ in almost every possible detail. Animals of all ages were used, each institution confining itself to the use of those of a certain age. The method of feeding differed from place to place. The period elapsing between inoculation and the removal of the virus also varies considerably in different institutions. Some remove the vaccine at the end of three, others at the end of six, days; others choose a period of four or five days.

The lymph, put up for final distribution in capillary tubes, that is, tubes with both ends sealed in the flame, are sent out with small bulbs, to be used in ejecting the lymph upon the scarified area. Printed directions, issued with each lot of vaccine, describe the method for using the bulb.

The capillary tubes are sent out in lots of 3, 5, 10 or more, put up in glass, wooden and paper containers, in the order named. The latter may be sealed, and the whole sent as first-class mail matter. Physicians requiring vaccine lymph may, by addressing the State Board of Health, State House, Boston, obtain by return mail the number of tubes desired.

The total number of tube of vaccine virus issued by the Board during the seven years and two months ending Nov. 30, 1911, was as follows: —

	Tubes.
In 1904–05 (year ended Sept. 30, 1905),	23,970
During fourteen months ended Nov. 30, 1906,	31,805
In 1906–07 (year ended Nov. 30, 1907),	45,265
In 1907–08 (year ended Nov. 30, 1908),	48,768
In 1908–09 (year ended Nov. 30, 1909),	47,961
In 1909–10 (year ended Nov. 30, 1910),	76,690
In 1910–11 (year ended Nov. 30, 1911),	65,251
Total,	339,710

6. INSPECTION OF FOOD AND DRUGS.

The department of food inspection deals with the enforcement of the laws pertaining to the sale of adulterated milk, food and drugs, of arsenical wall papers and fabrics, and of cocaine and morphine and their derivatives. It also makes examination of certain poisons, liquors and turpentine for police authorities, and of paints, oils and turpentine for the Massachusetts district police.

The food and drug law of Massachusetts was passed in 1882, and its enforcement was placed in the hands of the State Board of Health. This law is the second in antiquity in the country, that of New York State being enacted one year earlier.

Previous to the passage of the law the Board had made numerous investigations concerning the purity of milk, food and drugs, and these studies were no doubt instrumental in the passage of the law.

In the third annual report, 1872, an article appeared by Dr. Frank W. Draper on "The Evil Effects of the Use of Arsenic in Certain Green Colors," in which he states that an awakening of the community to some appreciation of the dangers from the use of these colors would cause a cessation of demand for such papers. The correctness of Dr. Draper's reasoning was shown later in an investigation in 1900 just before the law relating to arsenic in wall paper went into effect.

In the same report Henry B. Hill, of Harvard University, presented an article upon "The Adulterations and Impurities of Foods," in which he described his investigations upon the action of acid fruits on tin and the adulteration of vinegar and coffee.

The fourth report, 1873, contained a "Report of the Character of Substances used for Flavoring Articles of Food and Drinks," by Dr. Henry K. Oliver, as a result of reported cases of sickness from eating "pistachio" ice cream. Prussic acid was found in the bitter almond oil supplied to the manufacturers of the ice cream. The report deals with the synthetic esters and essential oils used as flavors.

Dr. Derby, secretary of the Board, reports in the same year the results of an investigation of the "Food of the People of Massachusetts."

Dr. Arthur Nichols and Prof. James F. Babcock report upon the adulteration of milk, giving analyses of pure milk, of market milk and a history of Massachusetts milk legislation to date, with suggestions for the establishment of a minimum standard of composition below which milk could not be sold.

H. B. Hill reports his investigation upon impurities in food, dealing with confectionery and pickles.

The report for 1875 contained an article on "Our Meat Supply and Public Health," by Dr. C. S. Folsom, secretary of the Board, dealing with putrid, parasitic and infected meat.

The report of 1879 contains an article on "Trichinæ in Relation to the Public Health," by F. S. Billings, and one by Ellen H. Richards on the "Adulteration of Some Staple Groceries."

In 1882 new interest had been awakened in the subject by the action of the National Board of Trade, through whose committee of experts a bill was prepared "To Prevent the Adulteration of Food and Drugs." This bill, substantially in the form recommended, has been enacted by the States of New York, Massachusetts and Michigan.

After setting forth what should be held to constitute adulteration, and defining the terms "food" and "drug," the bill which was enacted provided that the State Board of Health, Lunacy and Charity should appoint inspectors and analysts; should make all necessary investigations and inquiries in reference to the food and drug supply; should make rules and regulations concerning the collection and examination of samples; and should establish standards not specifically provided. For carrying out the provisions of the act the sum of $3,000 was appropriated. The law was approved on May 28, 1882, and went into effect three months later; whereupon the Board appointed an analyst of foods and an analyst of drugs, who were directed to collect and examine samples, with such assistance as they might require, the appropriation being not large enough to permit the employment of regular inspectors.

The investigations made in the two fields showed that the market was in a most deplorable condition. In spite of the fact that the law relating to the inspection and sale of milk had been in existence for many years, the milk supply was found to be especially poor, adulteration being almost universally practiced in the cities and large towns. So great was this evil that in the following year, 1883, the Legislature amended the act by increasing the appropriation to $5,000, with the proviso that two-fifths of the whole should be expended in enforcing the milk law. Accordingly, two additional analysts were appointed, whose sole duty it was to look after this part of the work.

Owing to the conditions found by the several analysts to exist in their different fields, the Legislature of 1884 made further amendments of the food and drug act, the most important of which increased the appropriation to $10,000, whereof not less than $6,000 should be devoted to the enforcement of the laws relating to milk and milk products. This

enabled the Board to appoint regular inspectors, who, by law, were clothed with all the authority given to local inspectors.

The general law relating to food and drugs was not materially amended between 1884 and 1901; but in the latter year it was strengthened by the addition of a section prohibiting the use of certain preservatives, unless their presence and percentage are clearly set forth on the label in letters of a certain size, and by further legislation regulating the manner in which so-called compounds shall be labelled so that the purchaser may know their percentage composition. The amendment relative to the use of preservatives settled a much-vexed question; for, while the law prohibited the sale of foods containing ingredients injurious to the health of the consumer, authorities are by no means in agreement as to whether certain of the substances employed as preservatives exert an injurious influence on the system. The amendment waives the question, and leaves it to the consumer to decide whether he cares to assume the risk; but the vendor must acquaint him of the fact that the product is chemically preserved.

The sum placed at the disposal of the State Board of Health, which has had charge of the administration of the general law since its re-establishment as a separate Board in 1886, has been increased from time to time to $17,500, which is its present annual appropriation.

In the annual report of the State Board of Health for 1883 appears the report on food and drug inspection covering the work of 1882 and 1883. The analysts employed were Dr. Edward S. Wood, analyst of food, Dr. Bennett F. Davenport, analyst of drugs, and Dr. Charles Harrington and Prof. Charles A. Goessmann, analysts of milk. The report of the analysts of milk for this year, compared with the report of 1911, gives a good idea of the value of food inspection to the community. In 1883 there were examined 305 samples of milk with an average composition of 11.56 per cent. total solids. In 1911 the average of 4,630 samples, including those skimmed and watered, was 12.78 per cent. solids, 4.10 per cent. fat.

During the first eight years of the law the analyses of samples was conducted by the analysts of the Board in their own laboratories, but in the year 1891 most of the work was placed in charge of one chemist, Dr. Charles P. Worcester, in a small laboratory established by the Board in an office building, where it was conducted until the present laboratory in the State House was ready for occupancy, in 1895. Dr. Worcester occupied his position until his death, Oct. 9, 1898. He was succeeded by his assistant, the late Albert E. Leach, who resigned, on account of ill health, in 1909. He was succeeded by his assistant, Hermann C. Lythgoe, the present incumbent.

The yearly reports of the Board since 1883 show a gradual improvement in the condition of the food supply of the State, and at present there is but little adulteration practiced except in the case of milk. Milk has been and always will be extensively adulterated, on account of the faciilty with which adulteration can be practiced. There is no doubt but that the market would be flooded with adulterated milk if inspection ceased, because unscrupulous dealers would adulterate their milk, selling it at a lower price, and the public would buy the cheaper article.

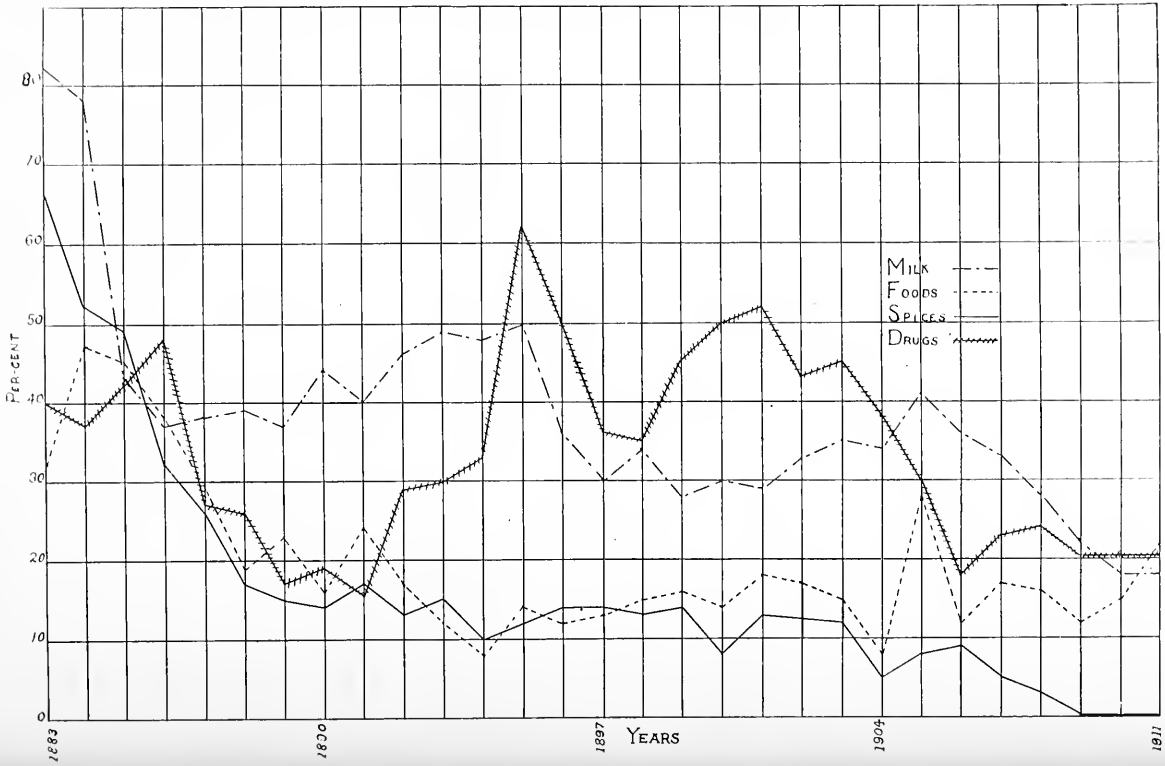
The chart giving the ratio of the adulteration of food and drug samples collected from 1883 to 1911 shows the value of the work of the department. This is particularly pointed out in the case of spices which have been systematically examined, and the dealers in the adulterated samples either notified or prosecuted, resulting in a gradual diminution in adulteration from 66 per cent. in 1883 to 0 in 1909–10 and 1911.

The occasional increases in adulteration in some years is due to a change in the character of the samples collected. Thus, if a particular variety of food or drug has been found to be pure for two or three years, the collection of that substance will cease and more energy will be expended upon those substances showing a higher ratio of adulteration.

Fluctuations in milk adulterations occur as more or less samples are collected from suspected producers rather than from the retailers. Of the total samples collected, the following are the percentages of adulteration during the past twenty-nine years: —

	Per Cent.		Per Cent.
1883,	50	1898,	27
1884,	58	1899,	29
1885,	44	1900,	33
1886,	42	1901,	33
1887,	33	1902,	32
1888,	28	1903,	31
1889,	26	1904,	25
1890,	27	1905,	26
1891,	27	1906,	23
1892,	31	1907,	25
1893,	30	1908,	22
1894,	31	1909,	18
1895,	42	1910,	17
1896,	34	1911,	19
1897,	29		

Diagram Illustrating the Variation of Percentages of Samples of Food and Drugs Found Adulterated by the Massachusetts State Board of Health



In 1906 a law was passed prohibiting the sale of cocaine or of proprietary medicines containing cocaine which had been advertised as unsalable by the State Board of Health. As a result of the enforcement of this law the sale of catarrh powders, asthma cures and similar preparations containing cocaine has been practically eliminated. The value of this work has been enhanced by the passage of laws prohibiting persons from having on their person or being present where opium, cocaine or other hypnotic drugs are kept except for legitimate purposes. This makes it undesirable to carry cocaine or morphine, and no doubt prevents to some extent the habit of using such drugs.

Elsewhere in this pamphlet is given a list of special papers relating to food and drugs published in the reports of the Board and in other journals.

7. INSPECTION OF DAIRIES.

Recognizing the well-demonstrated importance of an improved milk supply in its relation to the public health, the Board, acting under its general authority, began on March 1, 1905, a systematic investigation of dairies and the conditions under which milk is produced for public sale. The examination embraces an inquiry into the health and condition of cleanliness of the cows, the sanitary condition of the stables, the water supply, the methods of drawing, cooling, handling and transportation, and other matters germane to the subject.

A separate report is made on each dairy by the inspector to the secretary of the Board, who determines what changes, if any, in conditions or methods are desirable. In each instance the producer is advised as to what changes are deemed necessary in the interest of a wholesome milk supply. At the same time the local health authorities of the city or town wherein the milk is being produced or sold are notified, and they are requested to lend their assistance in securing improved conditions, and if the milk is being handled by contracting concerns, similar letters are sent to them.

The investigation demonstrated from the start its necessity, for a condition of affairs was disclosed which was deplorable. It is true that in most cases the objectionable conditions were susceptible of improvement without the expenditure of money and without involving anything more than ordinary care in the matter of common cleanliness.

The inspection of dairies through the Commonwealth has been continued up to the present time, with more or less gratifying results. The filthy and revolting conditions found at the inception of the work are seldom found now; there has been marked improvement in the production of milk all along the line. The agitation for a clean, wholesome milk supply has been taken up by the milk producer, dealer and consumer; cities and towns are uniting in their efforts to improve their milk supplies. While the conditions at the source of the milk supply are much improved, a strong concerted action for a continuance of such improvement cannot be expected until the proper authority is placed in the hands of a central body such as the State Board of Health.

The following table shows the number of dairies examined each year from 1905 to 1911, inclusive. It also indicates the number of dairies where objectionable conditions were observed, as well as the number where conditions were commendable.

Inspection of Dairies, — 1905–11.

Year.	Total Number of Dairies examined.	Number of Dairies where One or More Objectionable Features were observed.	Number of Dairies found to be without Objectionable Features.
1905,	2,151	1,720	431
1906,	3,267	2,219	1,048
1906, outside dairies,	154	138	16
1907,	2,054	1,350	704
1907, outside dairies,	660	455	205
1908,	2,213	1,028	1,185
1908, outside dairies,	18	7	11
1909,	1,439	758	681
1909, outside dairies,	332	159	173
1910,	1,983	700	1,283
1910, outside dairies,	70	37	33
1911,	2,067	736	1,331
1911, outside dairies,	2	1	1
	16,410	9,308	7,102

8. THE STATE INSPECTORS OF HEALTH.

In 1907 the Legislature of Massachusetts enacted a law whereby the State was divided into health districts and a physician was appointed in each district as State Inspector of Health. The original number of districts was 15, was later changed to 14, and was recently reduced by the State Board of Health to 12.

The duties of the State Inspectors of Health are in part advisory, and in part executive. The following is a brief outline of their powers and duties: —

I. Advisory Authority.

1. Inquiry and Action concerning Influences and Diseases that are or may be Dangerous to the Public Health.

The State Inspectors of Health are authorized to gather all information possible concerning all influences that are or may be dangerous to the public health and concerning the prevalence of tuberculosis and other communicable diseases. They disseminate knowledge as to the best methods of preventing the spread of diseases dangerous to the public health, and take such steps as, after consulting with the State Board of Health and the local health authorities, are deemed advisable for their eradication.

2. Dealings with Local Health Authorities as to: —

A. Rules and Regulations.

The State Inspectors of Health have been of considerable assistance to local health authorities in aiding them draft rules and regulations; and as the work of the local authorities is gradually placed on a higher plane, the men can be of even greater assistance, under the guidance of the State Board of Health, in obtaining uniformity in health work throughout the State.

B. Diseases Dangerous to the Public Health.

The State Inspectors of Health: —

(*a*) Consult with the local health authorities as to the best methods of preventing the spread of diseases dangerous to the public health.

(*b*) Advise the local authorities to urge physicians to report any known case of such a disease and to see that the notification laws are enforced.

(*c*) Investigate and report to local boards of health any known cases of ophthalmia neonatorum, so that the law requiring local boards of health "to take such immediate action as they may deem necessary in order that blindness may be prevented" may be enforced.

(*d*) Assist the local authorities as to the manner of caring for persons found ill in a neglected condition with such disease.

(*e*) Advise and assist local authorities in the enforcement of quarantine.

(*f*) Report to the State Board of Health and the proper local health authority every communicable disease discovered in a tenement workshop.

(*g*) Notify the State Board of Health and the proper local health authority of the existence of any such disease in factories and workshops.

C. Nuisances and Causes of Sickness.

In the work of abating nuisances the State Inspectors of Health advise local authorities as to the prevention of conditions which are dangerous to health, or which are offensive to the senses and render habitations uncomfortable.

D. Sanitation of Tenement Homes.

The State Inspectors of Health have been of considerable assistance to the local authorities in dealing with the problem of the sanitation of tenement homes. A high standard of sanitation in factories, brought about largely by rigid inspection, should go hand in hand with improved home conditions, particularly the tenement homes.

E. Statistics.

Efforts have been made to bring about uniformity in recording statistics relating to health work of all kinds.

3. Inquiry concerning the Health of Minors employed in Factories.

The work of obtaining information concerning the health of minors employed in factories calls for a knowledge of the ill health or physical unfitness of the minors. It involves obtaining personal and family histories, recording observations, and, in a considerable proportion of cases, making physical examinations.

4. Sanitation of School Buildings.

The law requires the State Inspectors of Health to make such examinations of school buildings as in the opinion of the State Board of Health the protection of the health of the pupils may require.

5. Matters relating to Water Supply and Sewerage.

The State Inspectors of Health, by intelligent co-operation, assist the State Board of Health materially in forwarding the work of the water supply and sewerage department. The law provides for adequate supply of pure drinking water for factory employees, and for proper disposal of sewage from factories and foundries.

II. Executive Authority.

1. Sanitation of Factories, Workshops and Other Industrial Establishments.

The work relating to the sanitation of factories, workshops and other industrial establishments includes the enforcement of certain laws. It also includes the study of the effect of occupation upon the health of persons employed in such establishments.

2. Exclusion of Minors from Occupations deemed to be Injurious to Health.

In the enforcement of the law which provides for the exclusion of minors from occupations or processes deemed by the State Board of Health to be injurious to health, the State Inspectors of Health consider carefully the varying conditions associated with a given occupation or process, as well as the condition of health of each minor at work.

3. Sanitation of Tenements where Clothing is made.

The primary object of inspection of tenement workrooms is to guard the public health from the spread of contagious diseases by means of infected wearing apparel. The work accomplished has resulted in the maintenance of higher sanitary standards in the congested tenement homes. Moreover, the friendly visits to the homes and the close personal contact with the workers have been a great educational force in the development of higher standards of hygienic living.

4. Inspection of Mercantile Establishments.

Inspection of mercantile establishments is made (*a*) to determine whether a sufficient number of seats are provided for women employees and whether there are proper toilet rooms for both sexes in such establishments, and (*b*) to enforce the statute provisions relating thereto.

5. Sanitation of Stationhouses.

In accordance with the law providing for an examination of the sanitary conditions in stationhouses, houses of detention and lock-ups in the Commonwealth, the State Inspectors of Health consider the ventilation, lighting, heating,

construction of cells, care and use of bedding and dishes used for food, method of sewage disposal, and method of supplying drinking water to prisoners in all such buildings.

6. Sanitation of Slaughterhouses.

Under the existing laws all slaughterhouses are subject to inspection by the State Inspectors of Health.

Of the many duties imposed by the Legislature upon the State Inspectors of Health, none are of greater importance or more far-reaching in their effects upon the conservation of the health of the inhabitants than is the requirement that State Inspectors of Health inform themselves concerning all influences that are, or may be, dangerous to the public health within their districts, and to gather all possible information relative to the prevalence of communicable diseases, and to co-operate with the local health authorities in their eradication.

Acting in an advisory capacity, the State Inspectors of Health have been intermediaries between the State Board of Health and the local health authorities, thus making the resources of the State available to the small communities throughout the State. Frequent conferences are held by the State Inspectors of Health with the local boards of health in the various districts, and assistance is rendered by them on a great variety of problems on health matters which is apt to come up in any community.

The State Inspectors of Health, moreover, keep in touch with the incidence of communicable diseases in the respective cities and towns within their districts, and if it appears that an unusually large number of cases of a communicable disease occur, or if any outbreak occurs in any place within a district, the State Inspector of Health makes an immediate investigation to determine, if possible, the source of infection.

Besides the general duties and advisory powers to local boards of health, the State Inspectors of Health were given the enforcement of all laws relating to the health of persons employed in industrial establishments. Massachusetts was thus the first State in the Union to recognize that the sanitary inspection of factories is essentially a health matter and should be under the charge of the central health authority of the State.

The work of the State Inspectors of Health for the last five years has already resulted in the accumulation of a vast amount of material on occupational hygiene and on factory sanitation. Not only have vast changes been brought about in the industrial establishments of the State,

but extensive investigations have been made of a great variety of industries and processes in which workers are exposed to influences dangerous to health. Special investigations have thus been made of a number of trades in which workers are exposed to dusts, to irritating and poisonous fumes, to extreme degrees of temperature and humidity, and to general unsanitary working conditions. The industries thus studied include the textile industry; the pearl industry; felt hat industry; mattress and curled hair industry; the shoe industry; the rubber industry; the making of jewelry; metal polishing and buffing; a group of industries in which workers are exposed to lead poisoning, such as printing, stereotyping, monotyping, linotyping, electrotyping, paint manufacturing, potteries and manufacturing of tile; foundries; laundries; cigar factories; candy factories and the clothing industry.

As the direct result of the investigations and observations of the State Inspectors of Health and of the reports thereon to the State Board of Health, legislation of inestimable value in protecting the health of young persons was enacted in 1910 whereby minors are excluded from trades and processes which are designated by the State Board of Health as injurious to health.

The Legislature of 1912 enacted a law creating the State Board of Labor and Industries. All duties of the State Inspectors of Health relative to the enforcement of laws in factories, workshops and mercantile establishments are by that law transferred to the newly created department. The State Inspectors of Health will now, therefore, devote practically their whole time investigating the occurrence of diseases dangerous to the public health, and acting in advisory capacity to the local boards of health.

9. MEMBERS OF THE STATE BOARD OF HEALTH FROM 1869-1912.

MEMBERS OF THE STATE BOARD OF HEALTH FROM ITS ORGANIZATION IN 1869 TO 1879.

P. Emory Aldrich,	1869–72
Henry I. Bowditch, M.D., *Chairman*,	1869–79
Wm. C. Chapin,	1869
R. T. Davis, M.D.,	1869–79
George Derby,	1869–73
C. F. Folsom,	1874–79
G. V. Fox,	1871–72
R. Frothingham,	1869–79
J. C. Hoadley,	1873–79
T. B. Newhall,	1873–79
Warren Sawyer,	1869–72
David L. Webster,	1873–79

MEMBERS WHO SERVED ON THE COMMITTEE ON HEALTH OF THE COMBINED BOARD FROM 1879 TO 1886.

Henry I. Bowditch, M.D.
George P. Carter.
R. T. Davis, M.D.
J. C. Hoadley.
Alfred Hosmer, M.D.
Thomas Talbot.
Henry P. Walcott, M.D.

MEMBERS OF THE STATE BOARD OF HEALTH SINCE ITS RE-ORGANIZATION IN 1886.

Julius H. Appleton,	1886–90
John W. Bartol, M.D.,	1902–07
Theodore C. Bates,	1887–88
Clement F. Coogan,[1]	1911–
Frank W. Draper, M.D.,	1886–1901
Joseph W. Hastings, M.D.,	1889–1904
James W. Hull,	1893–1911
Elisha U. Jones,	1886–1904
Thornton K. Lothrop,	1886–89
Robert W. Lovett, M.D.,[1]	1907–
C. E. McGillicuddy,[1]	1911–
Julian A. Mead, M.D.,[1]	1895–
Hiram F. Mills, C.E.,[1]	1886–

[1] Members of the Board at the present time.

Joseph A. Plouff,[1]	1911–
Charles H. Porter,	1893–1911
John M. Raymond,	1890–92
General Morris Schaff,	1891–92
Gerard C. Tobey,	1893–1911
Henry P. Walcott, M.D., *Chairman*,[1]	1886–
James White,	1886

Samuel W. Abbott, M.D., *Secretary*,	1886–1905
Charles Harrington, M.D., *Secretary*,	1905–09
Mark W. Richardson, M.D., *Secretary*,[2]	1909–
William C. Hanson, M.D., *Assistant to the Secretary*,[2]	1907–
F. P. Stearns, C.E., *Engineer*,	1886–1894
X. H. Goodnough, C. E., *Engineer*,[2]	1895–
Thomas M. Drown, M.D., *Chemist*.[3]	1886–1895
H. W. Clark, *Chemist*,[2]	1896–
Theobald Smith, M.D., *Pathologist*,[2]	1896–
Albert E. Leach, S.B., *Analyst of Food and Drugs*,	1900–1908
Hermann C. Lythgoe, S.B., *Analyst of Food and Drugs*,[2]	1907–

[1] Members of the Board at the present time.
[2] Connected with the Board at the present time.
[3] Consulting Chemist 1896-1904.

10. TITLES OF MANY OF THE SPECIAL INVESTIGATIONS CONTAINED IN THE REPORTS OF THE STATE BOARD OF HEALTH, AND PUBLICATIONS FROM THE BOARD'S LABORATORIES IN OTHER JOURNALS.

The annual reports of the State Board of Health contain the reports of the work of the various departments of the Board, together with special investigations or contributions during the year from any laboratory or department of the Board. Many of the researches carried on in the laboratories of the Board have been published in medical, chemical, engineering and other journals. The following is a list of titles of some of the principal special papers that have appeared in the reports of the State Board of Health, and an incomplete list of publications from the Board's laboratories in other journals.

ON MATTERS RELATING TO WATER SUPPLIES AND SEWERAGE.

1870. — Poisoning by Lead-Pipe used for the Conveyance of Drinking Water.

Mystic Pond and its Source of Supply.

1871. — Mill-Dams and Other Water Obstructions.

1872. — On Sewerage; Sewage; the Pollution of Streams; Water Supply of Towns.

Drainage for Health.

1873. — The Present Condition of Certain Rivers of Massachusetts together with Considerations touching the Water Supply of Towns.

The Use of Zinced or Galvanized Iron for the Storage and Conveyance of Drinking Water.

1875. — A Special Report on —

1. The Pollution of Rivers.
2. The Water Supply, Drainage and Sewerage of the State from a Sanitary Point of View.
3. The Disposal of Sewage.
4. Summary and Recommendations.

Defects in House Drainage and their Remedies.

The Surface Drainage of the Metropolitan District.

1876. — The Pollution of Streams.

Sewerage; its Advantages and Disadvantages, Construction and Maintenance.

1877. — Drainage and Health; Sewerage, and the Pollution of Streams.

The Filtration of Potable Water.

1878. — Common Defects in House Drains.

1879. — Contamination of Well Waters.
The Pollution of Streams.
Algæ observed in a Storage Basin of the Boston Supply, and Some Impurities of Drinking Water caused by Vegetable Growths.
The Effect on Health of Certain Algæ in the Mystic Water Supply.
The Drainage of Summer Hotels and Country Boarding Houses.

1880. — The Pollution of Streams.
Separate System of Sewerage.

1882. — The Sewerage of Nahant.

1883. — Tubular Wells for Domestic Water Supply.
Reports Relative to the Sewerage and Sanitary Conditions of Nantucket.

1885. — Disposal of Sewage at the Massachusetts Reformatory.

1889. — Report upon the Pollution of Ice Supplies.

1890. — Examination of Water Supplies and Purification of Sewage and Water by Filtration.
Suggestions as to the Selection of Sources of Water Supply.
Typhoid Fever and its Relation to Water Supplies.
Special Reports on the Early Work at the Lawrence Experiment Station. Two Volumes. Mentioned previously.

1892. — Interpretation of Water Analysis and the Amount of Dissolved Oxygen in the Water, Ponds and Reservoirs at Different Depths in Winter under the Ice, and the Mineral Contents of Some Waters in Massachusetts.
A Study of Odors observed in the Drinking Waters of Massachusetts.
Seasonal Distribution of Microscopic Organisms in Surface Waters.
Experiments upon the Purification of Sewage at the Lawrence Experiment Station.
Experiments at the Lawrence Experiment Station upon the Purification of Water by Sand Filtration.
Some Physical Properties of Sand and Gravels with Special Reference to their Use in Filtration.
Sewage Disposal of Cities and Towns of Massachusetts by Intermittent Filtration.
Report upon Artificial Ice made in Massachusetts.

1893. — On the Amount and Character of Organic Matters in Soil and its Drawing on the Storage of Water in Reservoirs.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station.
The Filter of the Water Supply of the City of Lawrence and its Results.

1894. — Composition of the Water of Deep Wells.
The Bacterial Contents of Certain Ground Waters.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station.
Physical and Chemical Properties of Sands.

1895. — Sewage Purification of the Cities and Towns of Massachusetts.
The Hardness of Water and Methods by which it is determined.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1895.
Methods employed for the Quantitative Determination of Bacteria in Sewage and Water.

1896. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1896.

1897. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1897.

1898. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1898.
An Investigation of the Action of Water upon Lead, Tin and Zinc with Special Reference to the Use of Lead Pipes in Massachusetts Water Supplies.
Purification of the Sewage of Cities and Towns in Massachusetts.

1899. — The Occurrence of Iron in Ground Waters and Experiments on Methods of Removal.

1900. — The Action of Water upon Metallic or Metal-lined Service Pipes and Methods for the Separation and Determination of Metals in Water.
An Investigation in regard to the Retention of Bacteria in Ice when Ice is formed under Different Conditions.
Studies of the Efficiency of Water Filters in removing Different Species of Bacteria.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1900.
The Examination of Spring Waters.

1901. — Experimental Filtration of the Water Supply of Springfield and Ludlow, Mass.
A Study of the Stability of the Effluent of Sewage Filters of Coarse Materials, including Investigations upon Putrefaction and Secondary Decomposition.
Bacteriological Studies at the Lawrence Experiment Station with Especial Reference to Determination of B. Coli.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1901.

1902. — On the Value of Tests for Bacteria of Specific Types as an Index of Pollution.
Effect of Sewage Disposal in Massachusetts.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1902.

1903. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1903.

1904. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1904.

1905. — Experiments on the Removal of Organisms from the Waters of Ponds and Reservoirs by the Use of Copper Sulphate.
Investigations concerning Absorption and Sedimentation of Copper Sulphate used as an Algicide and concerning the Bactericidal Properties of Copper and Copper Sulphate.
Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1905.
Studies on the Pollution of Shellfish.

1906. — Experiments on the Purification of Sewage and Water at the Lawrence Experiment Station in 1906.
Significance of the Numbers of Bacteria in Water and Sewage Developing at Different Temperatures.

1908. — A Review of Twenty-one Years' Experiments upon the Purification of Sewage at the Lawrence Experiment Station.

1909. — Disposal and Purification of Factory Wastes or Manufacturing Sewage.

1910. — Studies of the Relative Corrosion of Metal Pipes by Waters.

1911. — Experiments upon the Disinfection of Sewage and the Effluents from Sewage Filters.

Certain Publications in Journals other than Reports of the State Board of Health.

1888. — On the Color and Odor of Surface Waters.
The Loss on Ignition in Water Analysis.

1889. — The Determination of Chlorine in Water.
Effect of Temperature on the Determination of Ammonia by Nesslerization.
Determination of Organic Nitrogen in Natural Waters by the Kjeldahl Method.

1890. — The Determination of Carbonic Acid in Water, and the Bicarbonates of Lime and Magnesia.

1891. — On the Determination of Nitrates in Water.

1892. — The Study of Bacteria in Drinking Water.

1893. — The Removal of Pathogenic Bacteria from Drinking Water by Sand Filtration.

1894. — Sand Filtration of Water with Special Reference to Recent Results obtained at Lawrence, Mass.

1895. — On the Proper Reaction of Nutrient Media for Bacterial Cultivation.

1901. — Bacterial Purification of Water by Freezing.
The Pollution of Streams by Manufactural Wastes and Methods of Prevention.
Studies of Media for the Quantitative Estimation of Bacteria in Water and Sewage.

1902. — Report of the Chemist to the Charles River Dam Committee.

Notes on B. Coli and Allied Forms with Special Reference to Neutral Red Reaction.

On Classification and Identification of Bacteria with Description of Card System.

Removal of Color, Organisms and Odor from Water.

1903. — The Determination of Carbonic Acid in Drinking Water.

On the Value of Tests for Bacteria of Specific Types as an Index of Pollution.

1904. — Portable Outfit for the Determination of Carbonic Acid, Dissolved Oxygen and Alkalinity in Drinking Water.

Studies of Media for the Quantitative Estimation of Bacteria in Water and Sewage.

The Functions of Various Types of Bacteria in the Purification of Sewage, with Some Methods for their Quantitative Determination.

1905. — The Bacteriolysis of Peptones and Nitrates.

Upon the Use of Copper Sulphate in Water Supplies.

1906. — Collection and Preservation of Samples of Sewage for Analysis.

Some Data in Regard to the Comparative Disposition of Organic Matter by Sand, Contact and Sprinkling Filters.

The Use of Copper Sulphate in Water Filtration.

A Study of the Laws governing the Resistance of Bacillus Coli to Heat.

A Study of the Numbers of Bacteria developing at Different Temperatures and of the Ratios between such Numbers with Reference to their Significance in the Interpretation of Water Analysis.

Notes in Regard to the Determination of Copper in Water.

The Resistance to Decomposition of Certain Organic Matters in Sewage.

On the Bactericidal Action of Copper.

1907. — Filtration of Public Water Supplies.

Experiments with Methods for the Rapid Detection of Gelatin Liquefaction in the Determination of B. Coli.

Trickling Sewage Filters at the Lawrence Experiment Station.

1908. — Investigations of the Distribution of Sewage upon Trickling Filters.

Studies of Incubation Tests.

Studies on Direct Nesslerization of Kjeldahl Digestates in Sewage Analysis.

Apparatus and Expedients in the Bacteriological Laboratory.

Some Observations of Methods, Cost and Results of Sewage Purification Abroad.

1909. — Disinfection as an Adjunct to Water Purification.

1910. — Double Filtration of Water.

Methods for Testing Shellfish for Pollution.

1911. — A Study of Carbon in Sewage and Sewage Purification.

1912. — The Influence of Carbon upon Nitrification.

On Matters relating to Diseases Dangerous to Public Health.

1869. — The Prevention of Disease.

1870. — Trichina Disease in Massachusetts.
Charbon in Massachusetts.
The Cause of Typhoid Fever.

1871. — Vegetable Parasites and the Diseases caused by their Growth upon Man.
Smallpox in Massachusetts.

1872. — Infant Mortality.
Analysis of Correspondence and Some of the Causes or Antecedents of Consumption.

1873. — Cerebro-spinal Meningitis in Massachusetts in 1873.

1875. — Report of an Outbreak of Intestinal Disorder attributable to the Contamination of Drinking Water by Means of Impure Ice.
Report on Registration of Prevalent Diseases.

1876. — Registration of Deaths and Diseases.

1877. — Scarlet Fever.

1879. — Disinfection (Circular).
Trichinæ in Relation to the Public Health.

1880. — Intermittent Fever in Massachusetts.

1882. — Leprosy in its Relation to Public Health.

1883. — Trichinosis.

1884. — Epidemic Cholera.
Disinfection and Disinfectants.

1885. — Malaria in Eastern Massachusetts.

1886. — An Inquiry into the Transmission of Infectious Diseases through the Medium of Rags.

1888. — Trichinæ in Swine.

1889. — Intermittent Fever in Massachusetts.
The Influenza Epidemic of 1889 to 1890.

1891. — A Geographical Distribution of Diseases in Massachusetts.

1892. — Reports upon Epidemics of Typhoid Fever in Massachusetts in 1892.

1893. — Isolation Hospitals for Infectious Diseases.

1894. — Report upon Experiments and the Effect of Feeding upon Trichinosis in Hogs.
Report upon an Epidemic of Typhoid Fever in Marlborough apparently due to the Effect of Skimmed Milk.

1896. — A Comparative Study of the Toxine Production of Diphtheria Bacilli.

1907. — The Occurrence of Infantile Paralysis in Massachusetts.

1908. — The Growth of Typhoid Bacteria in Milk.
Experimental Researches in Tuberculosis with Special Reference to Etiology and Pathology and Immunity.

On the Prevention of the Spread of Tuberculosis.
Milk as a Carrier of Infection.
The Occurrence of Infantile Paralysis in Massachusetts.

1909. — Infant Mortality and its Intimate Relation to the Milk Supply.
The House Fly as an Agent in the Dissemination of Infectious Diseases.
Ophthalmia Neonatorum: Preventive Treatment.
What is Diseased Meat and what is its Relation to Meat Inspection?
Animal Diseases transmissible to Man.
Origin and Prevalence of Typhoid Fever in Boston in 1909.
The Occurrence of Infantile Paralysis in Massachusetts.

1910. — Chemical Disinfection.
Insects as Carriers of Disease.
Antityphoid Inoculation.
The Occurrence of Infantile Paralysis in Massachusetts.

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